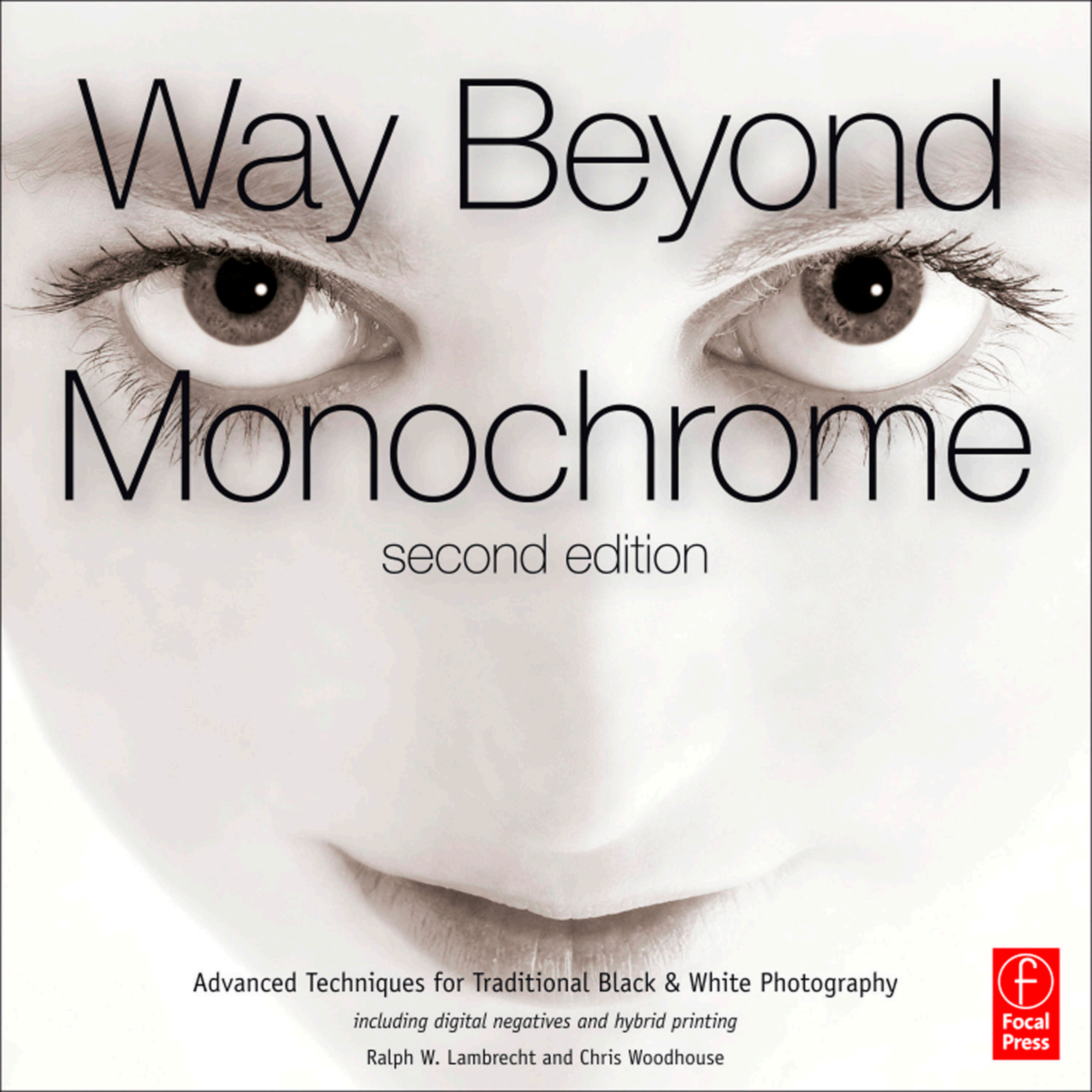
VISIT…

LANZAROTE
Caliente.com



# Way Beyond Monochrome

second edition

## Advanced Techniques for Traditional Black & White Photography

*including digital negatives and hybrid printing*

Ralph W. Lambrecht and Chris Woodhouse

Focal Press

# Way Beyond Monochrome

This page intentionally left blank

# Way Beyond Monochrome

## Advanced Techniques for Traditional Black & White Photography

second edition

by Ralph W. Lambrecht & Chris Woodhouse

ELSEVIER

Amsterdam • Boston • Heidelberg • London • New York
Oxford • Paris • San Diego • San Francisco • Singapore
Sydney • Tokyo
Focal Press is an imprint of Elsevier

Focal Press

Cover design by Ralph W. Lambrecht

Focal Press is an imprint of Elsevier
30 Corporate Drive, Suite 400, Burlington, MA 01803, USA
The Boulevard, Langford Lane, Kidlington, Oxford, OX5 1GB, UK

**© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved.**

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Details on how to seek permission, further information about the Publisher's permissions policies and our arrangements with organizations such as the Copyright Clearance Center and the Copyright Licensing Agency, can be found at our website: www.elsevier.com/permissions.

This book and the individual contributions contained in it are protected under copyright by the Publisher (other than as may be noted herein).

**Notices**
Knowledge and best practice in this field are constantly changing. As new research and experience broaden, our understanding, changes in research methods, professional practices or medical treatment may become necessary. Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds or experiments described herein. In using such information or methods, they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility. To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

**Library of Congress Cataloging-in-Publication Data**
Application submitted

**British Library Cataloguing-in-Publication Data**
A catalogue record for this book is available from the British Library.

ISBN: 978-0-240-81625-8

For information on all Focal Press publications visit our website at www.elsevierdirect.com.

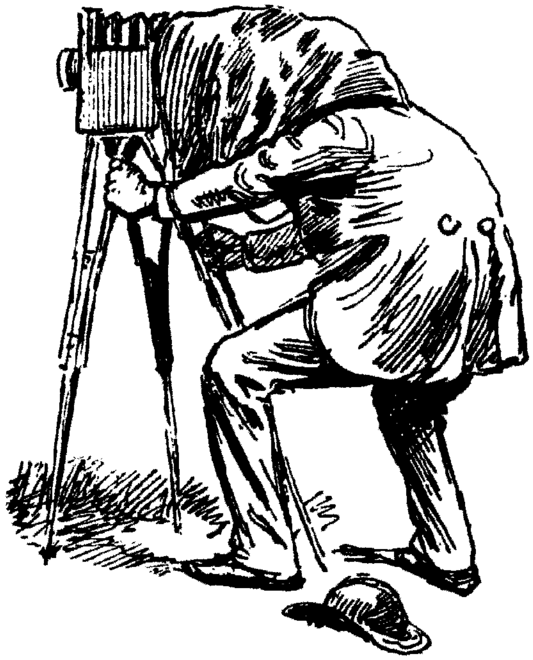
10 11 12 13 5 4 3 2 1

Printed in China

Working together to grow
libraries in developing countries

www.elsevier.com | www.bookaid.org | www.sabre.org

ELSEVIER BOOK AID International Sabre Foundation



Art is about being consciously creative. Understanding materials and processes is about taking control. This makes our work consistent and predictable. When materials, techniques and processes are not understood, artistic success depends on serendipity and is no longer intentionally conceived.

*—Ralph W. Lambrecht*

© 2002 by Frank Andreae, all rights reserved

How charming it would be if it were possible to cause these natural images to imprint themselves durably and remain fixed upon the paper.

*—William Henry Fox Talbot*

The discovery I announce to the public today is one of the small number which, by their principles, their results and the beneficial influence which they exert upon the arts, are counted among the most useful and extraordinary inventions.

*—Louis Jacques Mandé Daguerre*

The production of a perfect picture by means of photography is an art. The production of a technically perfect negative is a science.

*—Ferdinand Hurter*

In 1876, I induced Dr. Ferdinand Hurter to take up photography as a recreation, but to a mind accustomed like his to methods of scientific precision, it became intolerable to practice an art which, at the time, was so entirely governed by rule of thumb, and of which the fundamental principles were so little understood. It was agreed that we should jointly undertake an investigation with the object of rendering photography a more quantitative science.

*—Vero Charles Driffield*

One photo out of focus is a mistake, ten photos out of focus are an experimentation, one hundred photos out of focus are a style.

*—author unknown*

To consult the rules of composition before making a picture is a little like consulting the law of gravity before going for a walk.

*—Edward Weston*

Your first 10,000 photographs are your worst.

*—Henri Cartier-Bresson*

Photography is 90% sheer, brutal drudgery. The other 10% is inspiration.

*—Brett Weston*

Compensating for lack of skill with technology is progress toward mediocrity. As technology advances, craftsmanship recedes. As technology increases our possibilities, we use them less resourcefully. The one thing we've gained is spontaneity, which is useless without perception.

*—David Vestal*

# Contents

Foreword to the First Edition xi
Foreword to the Second Edition xiii
Preface and Acknowledgments xiv
Introduction xvi

## Part 1 The Basics

### From Visualization to Print

Eye and Brain 5
Pictorial Maturity 11
Photographic Quality 16

### Fundamental Print Control

Timing Print Exposures 23
Paper and Print Contrast 28
Basics of Photographic Printing 31
Archival Print Processing 35

### Presentation Is Everything

Mounting and Matting Prints 57
Print Spotting 76
Framing and Displaying Prints 81
What Size Is the Edition? 92

## Part 2 The Science

### Tone Reproduction

Introduction to the Zone System 105
Introduction to Sensitometry 110
Tone Reproduction 113
Image Gradation 120

### Image Capture

Imaging Paths 129
Sharpness and Depth of Field 131
Critical Focusing 145
Pinhole Photography 149
Basics of Digital Capture 157
Digital Capture Alternatives 169

### Negative Control

Introduction to Exposure 185
Development and Film Processing 193
Advanced Development 207
Creating a Standard 211
Customizing Film Speed and Development 214
Influence of Exposure and Development 225
Exposure Latitude 229
Pre-Exposure 233
Applied Zone System 239
C41 Zone System 246
Quality Control 251
Unsharp Masking 256
Masking for Complete Control 262
Digital Negatives for Contact Printing 275
The Copy-Print Process 282

### Advanced Print Control

Fine-Tuning Print Exposure and Contrast 295
Measuring Paper Contrast 302
Contrast Control with Color Enlargers 309
Exposure Compensation for Contrast Change 315
Basic Split-Grade Printing 318
Advanced Split-Grade Printing 324
Print Flashing 329
Paper Reciprocity Failure 336
Miscellaneous Material Characteristics 338
Factorial Development 340
Print Bleaching 343
Print Dry-Down 347

### On Assignment

Above Malham Cove 353
Cedar Falls 356
Clapham Bridge 359
Corkscrews 362
Portrait Studio Lighting 365
Ingatestone Hall 369
Heybridge 372
Karen 374
Light-Painted Flowers 376
Metalica 378
Alternative Processes 380
MonoLog 382
Parnham Doorway 384
Large-Format Nudes 386
Rape Field 389
St. Mary's of Buttsbury 393
Stonehenge 396
Summer Storm 400
Toothpaste Factory 402

## Part 3 Odds and Ends

### Equipment and Facilities

Image-Taking Equipment 409
Darkroom Design 421
How Safe Is Your Safelight? 428
Enlarger Light Sources 433
Sharpness in the Darkroom 438
Other Darkroom Equipment 449

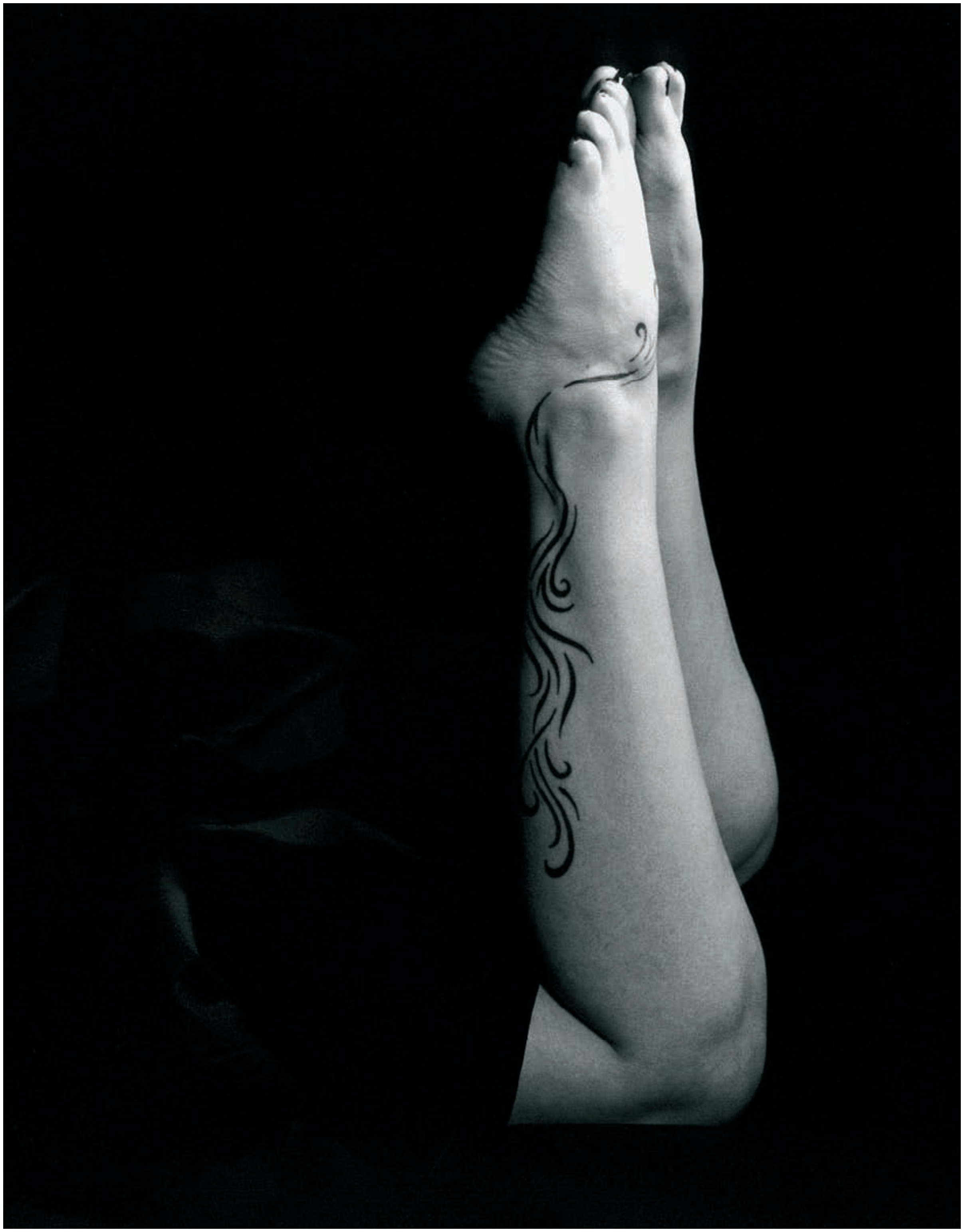
### Tools, Tips and Tricks

Identification System for Film Holders 463
How to Build and Use the Zone Ruler 466
How to Build and Use a Zone Dial 468
Make Your Own Shutter Tester 470
Make Your Own Test Strip Printer 472
Make Your Own Burning Card 477
Exposure, Development and Printing Records 480
Making Prints from Paper Negatives 483

### Appendix

Technical Fundamentals 491
Make Your Own Transfer Function 494
Photographic Chemistry 498
Basic Chemical Formulae 502
Tables and Templates 506

Glossary 528
Bibliography 530
Index 537



© 2000 by Ralph W. Lambrecht, all rights reserved

# Foreword to the First Edition

As I write this in the spring of 2002, many people are starting to believe that traditional, film-based, analog photography will soon be replaced by digital photography. However, as most people who take a close interest in these matters understand very well, the reality is likely to be rather different. We read about ever-increasing numbers of pictures being taken with digital cameras and how this is evidence of the replacement of film by the newer technology. Digital photography has clearly started to replace film in some areas, but only those where it offers overwhelming advantages. Two good examples are news photography because of the short deadlines, and catalogue photography because of the small image size and significant savings on film and processing costs. The arrival of the digital camera has meant that more pictures are being taken, and that's a good thing. While many of these are very different kinds of pictures, they are often simply visual notes. Film, however, remains a highly portable and very high quality storage medium, which is also, at least from the point of view of someone involved in film manufacturing, excellent value for money. It provides human readable images with good storage stability, which are free from the risk of software and equipment obsolescence that tends to threaten the long-term survival of digitally stored images. For these reasons alone, film will no doubt be with us for many years to come.

Digital photography is currently more a threat to color film, which has replaced B&W film in those fields where digital capture is becoming popular. However, the options for producing high-quality monochrome prints from digital files still need to be explored further. In my view, there are some interesting parallels here with the earlier replacement of B&W by color photography. Color initially replaced B&W in popular applications such as weddings and portrait photography where desirability of color images outweighed their considerable extra cost. In other areas, like snapshot photography, it happened later where color photography became more affordable, and the price advantage of B&W began to disappear. However, it never came close to eliminating B&W photography altogether. This is because the photographers who choose to work in B&W are using it as a medium for personal expression and not as an inferior substitute for color. These photographers actively prefer it, and they value the very high degree of creative control that is potentially available at all stages of the process, from camera filtration to print toning. To exploit this fully requires a great deal of skill and experience in the art of photography. This can be, and often is, acquired by a process of trial and error, but a more reliable route is through a thorough understanding of the underlying principles involved. Without this understanding, it is very difficult to get predictable results and to make the leap from occasionally good results to consistently excellent ones.

In my own continuing journey to becoming (I hope) a better photographer, I have been very grateful for the counsel of more experienced and skillful practitioners. With the decline of photographic clubs and societies, this has come mainly from books written by respected experts.

This book, from Ralph and Chris, is a very worthwhile addition to the available literature as it offers a wealth of practical advice, which is based on a very sound grasp of photographic theory and practice. I certainly hope that it will help many technically minded photographers to make real improvements in the quality of their negatives and prints. I also expect that we can look forward to many more years of analog B&W photography, because I believe that reports of its imminent total demise are much exaggerated.

*Mike Gristwood*
*ILFORD Imaging UK Limited*
*March 2002*

© 2002 by Ralph W. Lambrecht, all rights reserved

# Foreword to the Second Edition

When the first edition of this book was published in 2003, digital methods were already making inroads into many areas of photography. Since then, the revolution has been more or less complete for casual and commercial photography. In his foreword to the first edition, Ilford's Mike Gristwood predicted that traditional black and white photography would not be eclipsed by digital and would survive as the medium of choice for the more discerning and artistically minded practitioner. Not only is silver-based monochrome photography still very much with us, it is positively flourishing, and while some famous and long-established manufacturers have fallen by the wayside, there are smaller, leaner businesses stepping into the breach to ensure that traditional materials remain available.

In an encouraging move, many young photographers brought up with digital have started to explore the world of film-based photography and are enjoying the craft aspects of the process, which are largely absent whenever computers are involved. At the time of this writing, film cameras, accessories and darkroom equipment of the highest quality can be picked up secondhand for a fraction of their original value. Most will last a lifetime if properly cared for — unlike digital equipment and software, which demands continual upgrades more or less every six months or so, killing at a stroke the notion that digital is 'cheaper' simply because there are no film and processing costs.

The secret to successful film photography lies in a full understanding of the processes involved for the creation of the negative and subsequent print, as well as an ability to create pleasing images. This combination of art, craft and science is perhaps unique to traditional photography, and is certainly a major reason for my continuing interest in its pursuit.

This book is a rigorous and thorough approach to all aspects of monochrome photography but never loses sight of the fact that the final print is as much a work of art as of science. Many photographers enjoy the craft and science of photography, and they will find here as much reference information as they could ever need. Yet, photographers who have a definite idea of the desired outcome can select as much or as little as required to produce the fine print they visualized at the time of exposing the film.

While some of the science may appear daunting at first glance, especially to a reader new to the subject, it is presented in such a way that the reader can decide in how much depth he or she wishes to cover each subject. The first edition has been described as a 'technical tour de force', and with copies changing hands for many times the original cover price, it is evident that the basic premise of the authors was fundamentally sound. This greatly expanded second edition includes many more in-depth chapters, based on original research and exploding a few myths along the way. In addition, there are new chapters covering the more aesthetic aspects of photography, including visualization, print presentation and more, which should ensure that it remains the standard work on traditional monochrome photography for many years to come.

*Dr. Richard Ross*
*RH Designs*
*September 2009*

# Preface and Acknowledgments

Photography can be breathtaking and beautiful. It can represent a real or an imagined world. Yet, from its beginnings, photography constantly struggled to be accepted as 'real' art. There were those who claim artistic creativity is too constrained by the involvement of a highly technical process, which is a debate that is now refueled with the invention of digital imaging. Nevertheless, it requires the combination of creativity and craft to create fine art. A visionary, no matter how creative, without mastery of the photographic craft, will struggle to create a print that reflects the intended feeling or mood. On the other hand, the craftsman without creativity might be able to create beautiful prints, but they will have little artistic individuality. There is no essential difference between the artist and the craftsman. The artist is an exalted craftsman.

A common interest in good photography, combined with a fascination for fine-art printing and an appreciation for the craftsmanship involved, drew us together many years ago. We recognized that the final print is the only criterion by which all previous photographic steps can be judged and that poor technique can ruin the best print. Fortunately, good technique can be learned, but it proved difficult to find contemporary literature that competently addressed all of the topics and intricacies of creating fine-art prints successfully.

We felt that many of the recently published instructional books did not cover the technical aspects of printmaking in sufficient detail and failed to help discerning printers to progress. Therefore, we found ourselves frequently consulting good technical literature, published several decades ago and no longer available for sale. In addition, these books were rarely supported by commendable pictorial content and seldom made for an easy read. There were, however, many quality photographic publications with admirable image content. Nevertheless, these often fell short in offering creative advice or completely avoided revealing the techniques required to achieve the presented results. It seemed to us that the entire photographic community was separated into artists, darkroom practitioners and photographic scientists with limited interest in each other's work. Obviously, there was little chance for them ever to get together and write one book, covering in adequate detail all subjects required to produce skilled fine-art prints consistently and to support the technical advice with a respectable pictorial body of work. Since obviously no one else was working on this task, we picked up the challenge and set to work.

We took more than ten years to research, draft, write, edit, re-write and lay out the first and second edition, although our individual data collections started many years before we began. During this period, digital imaging made its presence known with a meteoric rise in sales and hype, and we felt obligated to research and include some digital monochrome techniques. All visual artists select a medium to communicate their message: for some, this is oil paint on canvas; for others, it is charcoal or watercolor on paper. We chose analog B&W photography. Frequently, when progress and innovation offer a new tool, it must be considered an additional choice and not a replacement, regardless of exaggerated predictions from overly eager proponents. Not all painters abandoned their paintbrushes when photography was announced in 1839, and similarly, fine-art prints will continue to be made with traditional materials in spite of the arrival of digital printing. Nevertheless, a new tool often provides additional possibilities that only Luddites ignore, and it offers the potential to improve on an otherwise mature technology, making it cheaper, quicker, simpler or better.

Unfortunately, many digital-imaging claims of cost and timesavings, simplicity and longevity have since proven to be premature. We have invested considerable research time, effort and money into every aspect of digital imaging, and it is our joint conclusion that there are obvious advantages to digital manipulation, but digital print quality is inferior to silver-gelatin prints in many ways. In reality, there is nothing cheap, quick or simple about digital imaging. It requires a considerable ongoing financial investment in hardware and software, a significant effort to become a proficient user and a tiring amount of work to get an image manipulated to satisfaction. Moreover, it has the common disadvantage of evolving technologies in which all investments are outdated before they have a realistic chance to appreciate.

Considering all of this, we are restricting the digital contents in the second edition to include digital capture, digital sensitometry and the making of digital negatives for the purpose of traditional printing to silver-gelatin papers. We purposely avoid detailed instructions about digital manipulation, because many competent publications already cover this exciting subject, and often-useful technique, in more detail than we ever could. For now, we will stay away from inkjet printing as a final output altogether and leave this topic to more frequently updated publications, since they can react more quickly to constant technology improvements in this area. At the same time, we have reorganized, updated and added to the first edition in all areas, to make this book as accurate and complete as possible. The result, we believe, upholds the best in current monochrome practice.

During the research phase for this book, we processed countless rolls of film and sheets of paper to evaluate the influence and significance of all known photographic variables. Being familiar with professional testing methods and statistical process control, we are aware that our test methods will not withstand scientific scrutiny. Be that as it may, we have taken all reasonable care that potential variables, not tested for, have been kept constant within a tolerance, where they could not influence the results as anything more than insignificant noise factors. Strictly speaking, many results presented in the book may only be valid for the particular materials tested and may not be applicable to others. Enough test details are given for you to recreate the tests with your favorite materials, nevertheless.

A book project, like this, cannot be accomplished without the help and support of some knowledgeable and experienced people. They all deserve our appreciation and gratitude. First and foremost, we thank Karen Lambrecht for patiently editing the text and asking countless clarifying questions. Without her effort, linguistic expertise and patience, this book would have never happened.

Many thanks for their support also goes to our friends in photography, Frank Andreae, Thomas Bertilsson, Nicole Boenig-McGrade, Don Clayden, Andreas Emmel, Brooks Jensen, Paul Kessel, Marco Morini, Michael R. Peres, Lynn Radeka, Henrik Reimann, Gerry Sexton, John Sexton, Steve Sherman, Peter De Smidt, Bernard Turnbull, Keith A. Williams and Hisun Wong, who contributed their excellent photographs to illustrate this book.

Special thanks to Howard Bond and Phil Davis for their initial guidance, introduction to the Zone System and early technical edits. Many thanks to Dr. Richard Zakia for the permission to use his valuable illustrations. Many thanks, as well, to Dr. Michael J. Gudzinowicz and Dr. Scott Williams (Rochester Institute of Technology), and to Douglas Nishimura (Image Permanence Institute) for sharing their knowledge on archival processing techniques. Finally, special thanks also to Ian Grant, Mike Gristwood (Ilford Imaging UK Ltd, retired) and Dave Valvo (Eastman Kodak Company, retired) for their continuing technical support and final technical edits. The combined help of all the people above, and the feedback, suggestions and encouragement we received from our readers of the first edition, made this book more authoritative, useful and accurate.

Ralph Lambrecht was born and educated in Germany. His interest in photography started when he was about seven years old and saw a B&W image emerging in the developer of his father's darkroom. His first camera was a Box Brownie handed down from his grandmother, followed by a post-war 6x6 rangefinder from his father.

As a young adult, Ralph emigrated with his wife and two children to the United States, where he worked and received a Masters Degree in Manufacturing Engineering from Lawrence Technological University in Michigan. While living in the US his interest in photography grew slowly into a passion, when he met accomplished photographers such as Howard Bond and Phil Davis, who taught him the basics of fine printing and the Zone System. Further photographic education followed, including a workshop with John Sexton in California, which ended with an unforgettable visit to Ansel Adams' darkroom.

His choice of equipment has become more sophisticated since the days of the Brownie, but he still uses mechanical cameras in medium and large format for all his fine-art photography. Traditional silver-gelatin film and fiber-base paper are his media of choice, and he enjoys performing all darkroom tasks himself. To him, an attractive presentation of the image is just as important as the photography itself. Consequently, he performs all mounting, matting and framing to archival gallery and museum standards. Since 1999, he is an Associate of the Royal Photographic Society and a Graduate Image Scientist since 2007. His work has been exhibited internationally from private galleries to the London Salon of Photography.

Ralph has been involved in adult education for over 20 years. As a photographic author, he has written for major photographic magazines, including *Camera & Darkroom*, *Black & White Photography*, *Photo Techniques*, *Fine Art Printer* and *View Camera* magazine. He is a regular on FotoTV and has contributed to several book projects, including *Schwarzweiß Fotografie Digital* and the fourth edition of *The Focal Encyclopedia of Photography*.

www.darkroomagic.com

# Introduction

This book is aimed at advanced amateur and semi-professional monochrome photographers, who have at some time developed and printed their own images, prefer the beauty of traditional photography, but want to improve their negative and print quality. The book will take the reader on a journey, which will transform 'trial and error' into confidence and the final print into something special.

This book explores techniques of print and negative control using example pictures, graphs and tables to communicate the information. Armed with this knowledge, the case studies show how and when to select which techniques to overcome problems on the path to the final print. The combination of technical background information and hands-on case studies creates a link between the 'how' and 'why' of traditional monochrome photography.

In this second edition, we have meticulously updated and extensively revised most chapters, adding better how-to pictures and improving all illustrations, while carefully rearranging the content and introducing several new topics. A brand-new section discussing the path from visualization to print, illustrating the interaction between eye and brain, and showing how craft and creativity can be combined to a quality photograph with impact was added. Print presentation was completely omitted from the previous edition, but is now covered in detail, including hands-on mounting, matting, spotting, and framing techniques as well as display considerations. Also, image capture has a more in-depth focus, including pinhole photography and digital capture. Film pre-exposure and latitude have been added, while film development has been extended. Making and printing with digital negatives is shown in detail. On the paper side, factorial development and print bleaching are new, while existing chapters were extended and improved. A few new case studies have been added. There is now a detailed section, showing all image-taking and image-making equipment we use on a regular basis. Plus, there are new do-it-yourself projects, including a shutter tester and how to make and work with paper negatives. In the appendix, we added a complete list of formulae to make your own darkroom chemicals, included a helpful glossary and extended the bibliography.

The focus of this book has not changed from the original goal to make high-quality silver-gelatin prints. For reasons already mentioned in the preface, digital output is not covered in this book at all. However, we still see a benefit in combining the new and creative opportunities of digital capturing with the proven quality of analog silver-gelatin prints. We have, therefore, included digital negative technology and sufficient information about digital capture to enable an experienced and dedicated darkroom worker to take advantage of these opportunities and combine the better of two technologies. Nevertheless, this is still predominantly a book about advanced techniques in traditional photography. We are certain that this new edition will provide something of interest for the practical and the more technically minded photographer.

For up-to-date information about this book, electronic sample chapters to show to friends, potential error corrections and many useful downloads, check the dedicated website at:

www.waybeyondmonochrome.com

*Ralph W. Lambrecht*
*Chris Woodhouse*
*June 2010*

Chris Woodhouse was born in Brentwood, England and during his teenage years was a keen amateur artist. Around this time, he was given his first camera, a Zenith B, which along with the discovery of his school darkroom started his interest in monochrome photography. At the age of 15, he joined a local photographic club, where he experienced his first large monochrome enlargements. Later, he received a Masters Degree in Electronic Engineering at Bath University, and after a period of designing communication and optical gauging equipment, he joined an automotive company. As a member of the Royal Photographic Society, he gained an Associate distinction in 2002.

During the last twenty-five years, he has pursued his passion for all forms of photography, including landscape, infrared, as well as portraiture, still life and architectural photography, mostly in monochrome. This passion, coupled with his design experience, led him to invent and patent several unique darkroom timers and meters, which are sold throughout the world. For a period of time, he turned his attention to digital imaging and the particular problems of making convincing monochrome inkjet prints. During this time, he wrote magazine articles on advanced printing techniques for *Camera & Darkroom*, *Ag+* and *Photo Techniques*.

In the dim peace of the darkroom, the negative is the beginning of a creative journey. Rather than assume that there is only one interpretation of a given negative, Chris explores alternative techniques, even with a familiar image, to suit the mood of the moment. Even after several interpretations, new techniques and experience often lead to better prints.

www.beyondmonochrome.co.uk

This page intentionally left blank

# Part 1

# The Basics

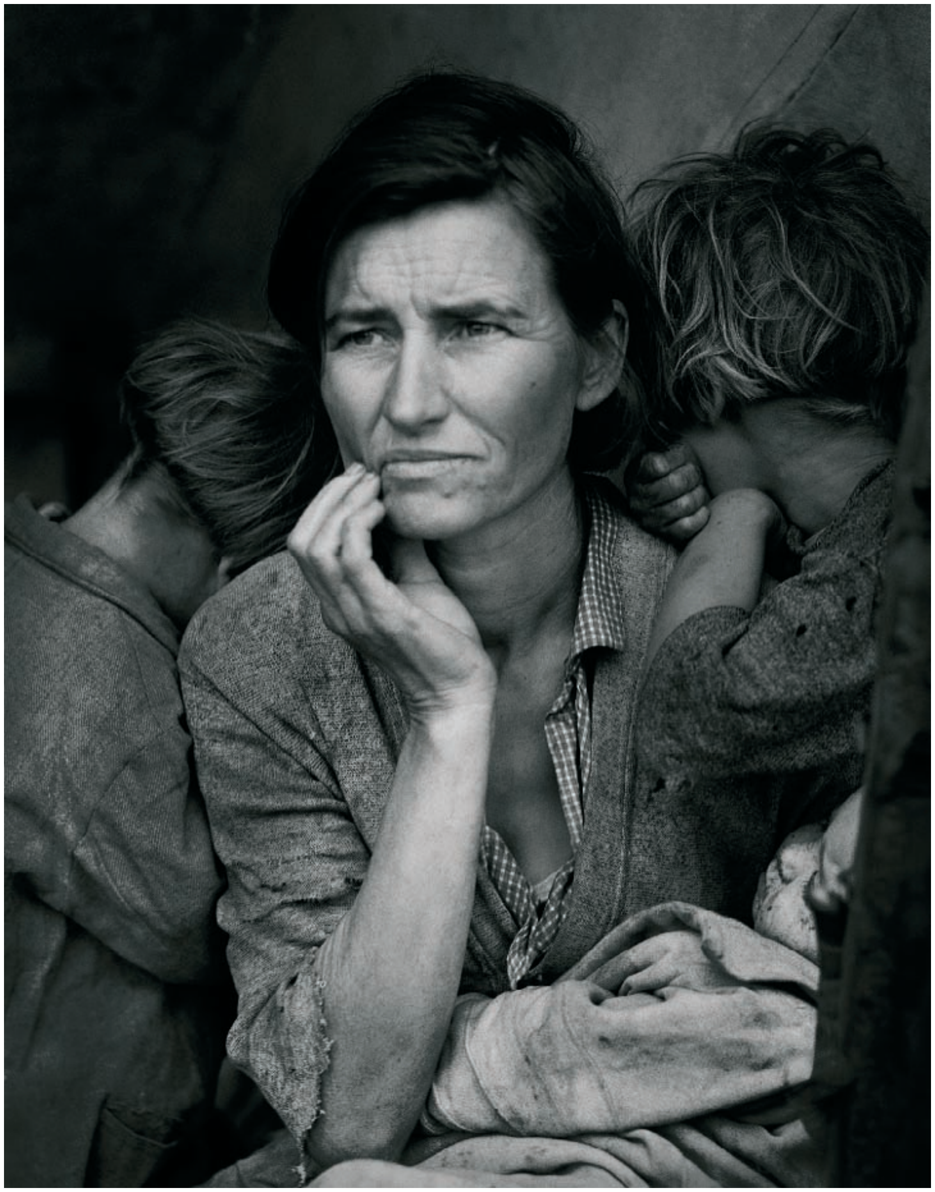
© 1996 by Hisun Wong, all rights reserved

# From Visualization to Print

This page intentionally left blank

# Eye and Brain

## Now you see it, now you don't



© 1936 by Dorothea Lange, Library of Congress, Prints & Photographs Division, FSA/OWI Collection, [LC-USF34-9058-C]

Photography is a form of visual communication and a category of modern visual art, which simply means that photographs are made to be seen by a group of people other than the artist himself. Successful artists, by intent or by instinct, make use of the fundamentals of human visual perception to improve their works of art. The human reaction to an image is a complex mix of physics, emotion and experience. However, understanding the limits of human vision allows the photographer to distinguish between essential and irrelevant technical accomplishment.

Three essential components are required to make human vision possible. There must be a sufficient amount of light, a light-gathering device to receive and arrange the light into structured optical information, and a processor to sort and administer this information to make it available for further decision and action. In the human visual system, eye and brain work closely together to gather, arrange and process the light around us.

### Electromagnetic Spectrum and Light

Modern humans are constantly exposed to a wide range of electromagnetic radiation (fig.1), but we hardly ever think about it, because our daily lives are filled with radio and television signals, radar, microwaves and the occasional x-ray exposure at the doctor's office. Low-frequency radiation, such as in radio and television signals, carries little energy and has no effect on the human body. It cannot be seen or felt. Higher frequencies, such as infrared radiation, can be felt by the skin as warmth, and even higher frequencies, such as UV and x-rays, carry sufficient energy to be harmful to humans with prolonged exposures. The highest frequencies, such as gamma radiation and cosmic rays, are packed with energy and would put an end to life on earth, if it were not for the planet's sensitive atmosphere and its

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50001-6

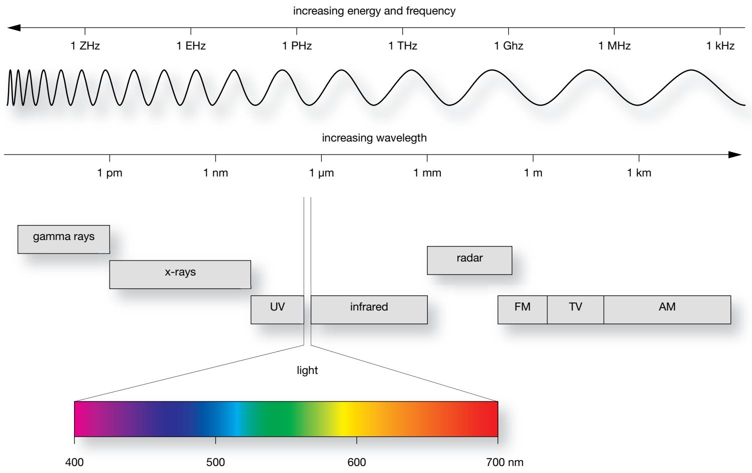


fig.1 Modern humans are constantly exposed to a wide range of electromagnetic radiation, but our eyes are sensitive to only a tiny range of these frequencies. They are the visible part of the spectrum, better known as ‘light’.

strong magnetic field to protect us. However, most electromagnetic radiation bombards us constantly without ever being detected by any of our senses. There is only a tiny range of frequencies, with a wavelength from roughly 400-700 nm, to which our eyes are sensitive. It is the visible part of the electromagnetic spectrum, better known as ‘light’. Within this range, the human eye sees changes in wavelength as a change of hue.

## The Anatomy of Human Vision

Before we get into the human visual system as a whole, it makes sense to initially understand the optical performance and visual functionality of eye and brain individually. What may come across as a small lesson in human anatomy is actually an essential introduction to the basic phenomena of human vision.

### The Human Eye

The human eye is often compared to a photographic camera, because the eye, a sophisticated organ capable of focusing an image onto a light-sensitive surface, is very similar to lens, camera and film (fig.2a), but with some significant differences in operation. The eye is a light-tight hollow sphere (sclera), containing an optical system (cornea and lens), which focuses the incoming light onto a light-sensitive surface (retina) to create an upside-down and reversed image. The amount of incoming light is controlled by the iris, which adjusts the aperture (pupil) as needed. The retinal image is converted into electrical impulses by millions of light-sensitive receptors and transmitted to the brain via the optical nerve.

Sharp focusing is controlled by the ring-shaped ciliary muscle, which surrounds the lens and is able to change its curvature. The muscle contracts to bulge the lens, allowing us to focus on nearby objects, and it relaxes or expands to flatten the lens for far-distance viewing. Changing the optical power of the lens, to maintain clear focus as the viewing distance changes, is a process known as accommodation. As we get older, the lens loses its flexibility, and it becomes increasingly more difficult to focus on close objects.

At infinity focus, the average lens has a focal length of roughly 17 mm. When fully open and adapted to low light levels, the pupil has a diameter of about 8 mm, which the iris can quickly reduce to about 2 mm in order to compensate for very bright conditions and to protect the retina from irreversible damage. In photographic terms, this is equivalent to an f/stop range from f/2 to f/8, covering a subject brightness range of 4 stops or a 16:1 ratio.

The retina is lined with light-sensitive receptors of two types, called rods and cones, which are only responsive to dim and bright light, respectively. At any given time, rods and cones provide a static sensitivity range of about 6 stops. However, rods and cones are able to dynamically alter their sensitivity by regulating the amount of a light-sensitive dye they contain. This enables the retina to adapt to a light-intensity range of 1,000,000:1 and adds 20 stops of dynamic sensitivity to its static range.

Fully building up the light-sensitive dye takes about 8 minutes in cones and up to 30 minutes in rods, which is a process called dark-adaptation. This explains why our vision improves only slowly, when we move from a bright to a dimly lit room. In the reverse process, rods and cones rapidly dispose of the dye, in order to safely adapt to a brighter environment. This is referred to as light adaptation and is typically completed within 5 minutes.

All rods are of a similar design, highly specialized for low-light sensitivity. However, cones come in three different varieties, and each kind produces a slightly different type of dye, making it sensitive to a different wavelength of light. This enables color vision, very similar to the way red, green and blue color receptors enable color imaging in digital camera sensors.

In summary, rods give us sensitive night vision (scotopic) and cones add colorful day vision (photopic) to our sense of sight (fig.2b). Combining the static and

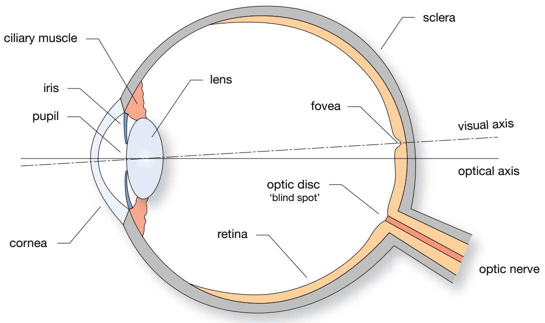

ciliary muscle
iris
pupil
cornea
lens
fovea
sclera
visual axis
optical axis
optic disc
'blind spot'
retina
optic nerve

fig.2a anatomy of the human eye

**Data Sheet of the Human Eye**

| | |
|---|---|
| focal length at infinity | 17 mm |
| comfortable min focus distance | 250 mm |
| typical aperture range | f/2 - f/8 |
| dynamic contrast range | 1,000 : 1 |
| max sensitivity range | 1,000,000,000 : 1 |
| standard visual angle | 1 arc minute |
| min optical resolution | 30 lp/degree |
| min reading resolution | 7 lp/mm |

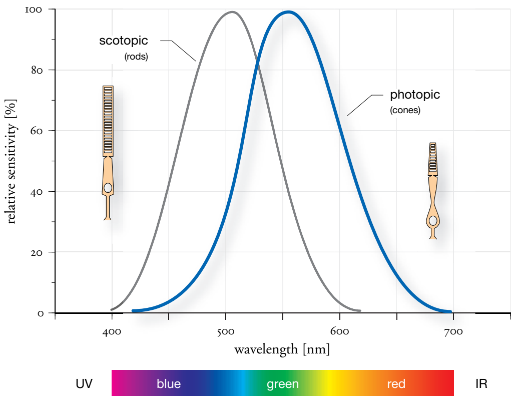


fig.2b spectral sensitivity of the human eye

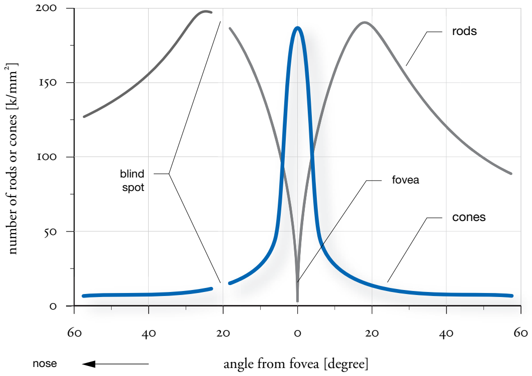


fig.2c population of rods and cones across the retina

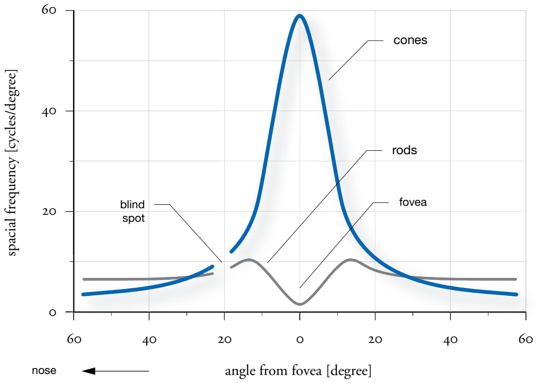


fig.2d visual acuity across retina

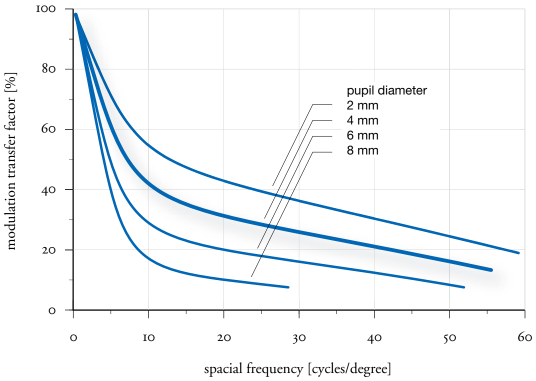


fig.2e visual acuity of the human eye

fig.2 The human eye is often compared to a photographic camera, because the eye, a sophisticated organ capable of focusing an image onto a light-sensitive surface, is very similar to lens, camera and film, but with some significant differences in operation.

dynamic sensitivity range of the retina, and adding the light-regulating support of the iris, provides the human eye with an enormous sensitivity range of 1,000,000,000:1 or almost 30 f/stops, as long as we give it the time to adapt to the dimmest and brightest lighting conditions possible.

There are millions of rods and cones distributed across the retina, but unlike the light-sensitive particles of a silver-gelatin emulsion, rods and cones are not distributed uniformly (fig.2c). Rods predominantly populate the outer surface area of the retina, whereas cones are primarily found around the center. Furthermore, there are two small areas on the retina that are quite different from the rest, and they deserve some special attention.

Close to the center of the retina is a small indentation, called the fovea. Its center, the fovea centralis, which is also the center of human vision, is only 1 mm in diameter. The fovea contains almost exclusively cones and very few rods. In fact, nowhere else on the retina are cones so densely populated as in the fovea. Here, the distance between cones is as small as 2.5 µm, and because of this, humans have excellent visual acuity in bright light. However, peak performance is limited to a relatively small angle of view, only a few degrees, concentrated around the fovea (fig.2d). Everything outside this narrow field of view blends into our relatively fuzzy peripheral vision. Nevertheless, about 50% of the optical impulses, sent to the brain, come from the fovea, and therefore, we can assume an optical resolution of the human eye of at least 30-60 line pairs per degree. The optical resolution of the eye also depends on the diameter of the pupil or, consequently, on illumination levels. Similar to a photographic lens, overall optical performance increases with decreasing aperture until diffraction takes over. Fig.2e shows how a wide-open pupil (8 mm) is limited to 30 lp/degree, a normal pupil opening (4 mm) achieves about 60 lp/mm, and a very small pupil (2 mm) can resolve up to 90 lp/mm. For the purpose of viewing photographs, we can assume an optical resolution of the human eye of 30-90 lp/mm, which is equivalent to viewing angles of 20-60 arc minutes and covers the range from standard to critical viewing conditions.

About 20° from the center of the fovea is the optical disc. This is the location where the optical nerve is attached to the eye. The optical disc is entirely free of rods or cones, and this complete lack of light receptors is the reason why the optical disc is also referred to as the 'blind spot'. Amazingly, the blind spot does not disturb human vision at all, because the brain makes use of surrounding optical impulses in order to fill in for the missing image information.

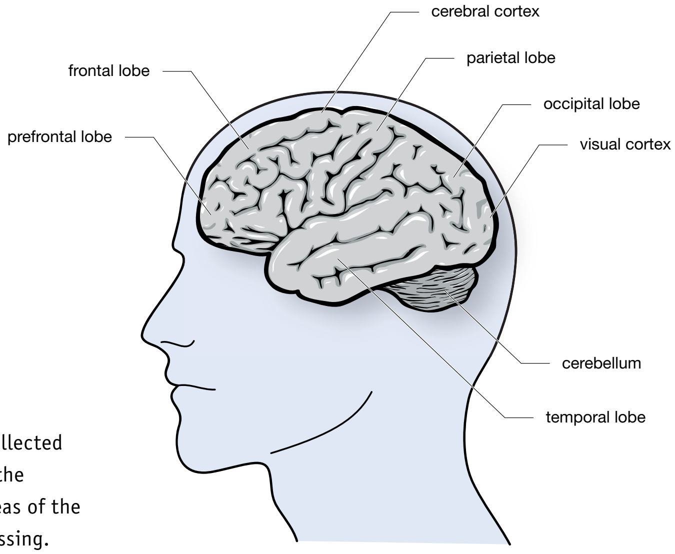


fig.3 The optical information, collected by our eyes, travels along the optical nerve to several areas of the brain for subsequent processing.

### The Human Brain

Comparing the human eye to a camera and lens does not fully appreciate the sophisticated functionality of this complex organ, but it sufficiently illustrates the eye's contribution to the human visual system. A similar association is often made by comparing the human brain to an electronic computer. The speed with which our brain processes visual input is about the only realistic comparison we can obtain from this analogy, because the brain is much more than just a pile of electronic circuitry.

The eye focuses an upside-down and reversed image onto the retina, where rods and cones convert the optical sensation into electrical signals, which travel along the optical nerve to several areas of the brain for subsequent processing. At first, the visual cortex, which is an area in the occipital lobe of the brain at the back of our head, differentiates between light and shadow, making out borders and edges and combining them into simple shapes. With support of the cerebral cortex in the parietal lobe, the new data is compared with previously memorized information and used to quickly recognize familiar faces and objects, while separating them from the background. But, visual processing does not stop there, because the information is now passed to the temporal lobe, where the meaning of what we have seen is interpreted, and faces and objects are given a name. In the frontal lobe, feelings are added, and finally, in the prefrontal lobe, we order our thoughts and decide what to do next, based on what we have seen.

This is a very simplified overview of the brain's function as part of the human visual system. What actually happens in our heads is far more complex, and much of the brain's functionality is still a mystery to modern science. All we know for sure is that whatever our brain does, it does it very, very quickly.

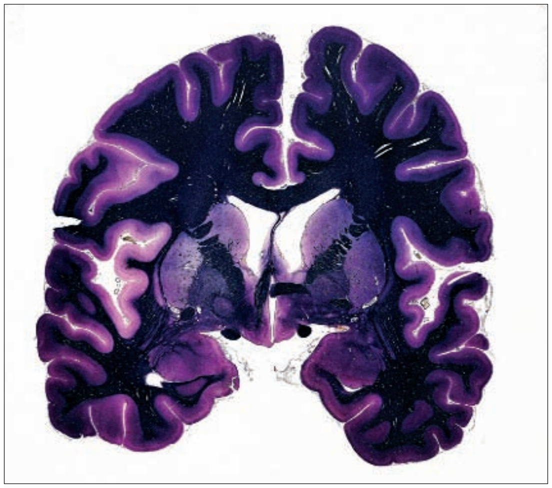


fig.4 This is a coronal section of a human brain, revealing small optic tracts that transport visual information from the eye to the brain, and also containing portions of the large and convoluted visual cortical regions, which translate light into vision.

(image © 2006 by Michael Peres, all rights reserved)

## The Human Visual System

The human eye is a camera, and the brain is a fast computer. While this grossly oversimplified statement roughly explains the contribution of both organs to human vision, it cannot illustrate the complexity and sophistication of the human visual system. What we believe to 'see' is a combination of the images created by our eyes and the brain's interpretation of them. In addition, the brain constantly supports the eye to optimize its optical performance and get the most visual information possible. Here are two examples:

The eye is able to recognize minute detail far beyond its inherent optical resolution of 1 arc minute. We can easily distinguish a thin wire against a bright sky down to 1 second of arc, but visual angles alone cannot explain why we can see the dim light of a star, thousands of light-years away. This astonishing capability is only possible with the support from the brain, because in reality, we do not look at a scene in fixed steadiness. Instead, our brain controls a constant and rapid scanning of the scene, referred to as saccadic movement, in an effort to gather more information than static observation alone would permit.

In addition, the brain keeps the eye in a constant state of vibration, oscillating it at a frequency of about 50 Hz. These subconscious micro tremors are involuntary, small angular movements of roughly 20 arc seconds, and they help to constantly refresh the retinal image produced by rods and cones. Without these micro tremors, staring at something would cause the human vision system to cease after a few seconds, because rods and cones do not record absolute brightness values but only respond to changes in luminance. The combined effort of saccadic movement and micro tremors are the reason for the amazing optical resolution of human vision and often the explanation for otherwise puzzling optical illusions.

The next example illustrates how our brain compensates for a natural deficiency of the human eye, and the large role the brain plays in determining what we see. From fig.2a, we know that there is a small area on the retina without visual receptors, called the optical disc, and a simple test will reveal its existence.

Fig.5 shows a plus sign on the left and a black dot to the right. Close or cover your left eye, and firmly stare at the plus sign with your right eye. While keeping your left eye closed, slowly move your head closer to the book. Keep staring at the plus sign, but be aware of the black dot on the right with your peripheral vision. At a distance of about 8 inches or 200 mm, the black dot suddenly disappears, at which point, its image falls on the blind spot of the retina. It may take you a few trial runs to get comfortable with this test.

Note that the brain is not willing to accept the lack of visual information caused by the blind spot. It does not disturb our normal vision, because the brain simply takes some visual information from the surrounding areas and fills in the blank spot with what, in reality, does not exist.

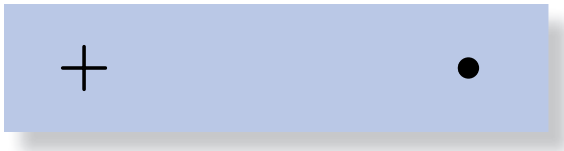


fig.5 This test is designed to reveal the blind spot of the human eye. Close your left eye, and stare at the plus sign with your right eye. While keeping your left eye closed, slowly move your head closer to the book. Keep staring at the plus sign, but watch the black dot on the right with your peripheral vision until it suddenly disappears when its image falls on the blind spot of the retina.

fig.6 Find yourself a willing participant and cover the playing cards with a piece of paper. Ask your test person to look at the cards, while uncovering them for less than a second. Now, ask the person what playing cards he or she remembers seeing. Most people will claim to have seen a king of hearts and an ace of spades. A more thorough look reveals that the card on the right is actually a fake, black ace of hearts.

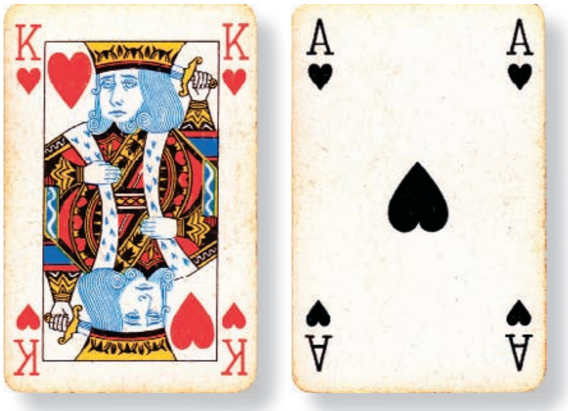


fig.7 Would there be a 'man in the moon' without the human obsession with faces and our prehistoric need to separate enemy from friend?

The last two examples demonstrated how the brain makes the most of the optical information it receives from the eyes. But, as we will see in the next example, sometimes the optical information only serves as supporting reference data for the brain to make a quick judgment.

Find yourself a willing participant and cover fig.6 with a piece of paper. Ask your test person to look at fig.6 and to uncover it for less than a second. Now, ask the person what playing cards he or she remembers seeing. Most people claim to have seen a king of hearts and an ace of spades. A more thorough observation of fig.6 reveals that the card on the right is actually a fake, black ace of hearts.

Of course, the official deck of playing cards contains no black ace of hearts, and consequently, the brain refuses to take the optical information given at face value, and prefers the result of a comparison with its previous experience, instead. The brain's conclusion is that the optical information, received from the eyes, must be wrong for whatever reason, and the card seen is more likely a common ace of spades. Nevertheless, a long enough look at fig.6 will eventually convince the brain that a black ace of hearts does indeed exist, and the test cannot be repeated with the same person, because its memory now allows for the existence of a black ace of hearts.

Human behaviorists believe that our brain is designed to make speedy decisions to protect us. When it comes to our safety, we need quick decisions. For example, the decision whether it is safe to cross a busy road or not does not rely on time-consuming calculations, considering the laws of physics. It's done within a split second, based on experience.

Less so in modern life, but very important to prehistoric human survival, was the ability to quickly separate enemy from friend. A familiar friendly face poses less of a threat than the uncertainty of an encounter with a stranger or the frightening appearance of a known enemy, who has done us harm in the past. For this reason, a large portion of our brain is dedicated to face recognition, and it works extremely well.

It works so well, in fact, that logic and reality are often forced to take second place. Faces seem to be hiding everywhere. We can detect them in bathroom tiles, wallpaper patterns and cloud formations. Our brain is constantly on the look out for facial features. Without the human obsession with faces, there probably would not be a man in the moon.

Experienced photographers and creative artists are aware, and make use, of the importance and power of facial expressions. The lead picture, 'Migrant Mother' by Dorothea Lange, does not reveal the actual circumstances where, when and why it was taken, but it summarizes the unfortunate fate of an entire family through the emotions written on one face.

# Pictorial Maturity

## Combining craft and creativity

Photography is an interesting mixture of practical science, craft, imagination, design and ultimately art. This book focuses predominantly on the craft surrounding competent fine-art B&W photography. Nevertheless, the authors are well aware that it requires the combination of creativity and craft to create fine art. Fine art always depends on the combination of unique, conscious creation and the mastery of tools and materials, through which this creation is made presentable to an audience.

A visionary full of original thought, but lacking the skill to turn imagination into a presentable product, will never reach an audience. A creative photographer, without adequate control over the technical aspects of the photographic process, will always struggle to create a print that reflects the intended feeling or mood. On the other hand, a skilled craftsman without any sense for creativity may produce a beautiful product, but it is, most likely, just an ordinary duplication of an already existing item. A photographer, trained in the technical aspects of photography but lacking the essentials of creativity, will be able to consistently produce technically perfect prints, but these prints will have little or no artistic individuality. Only when craft and creativity are joined can presentable art be created, and only when presented, can it reach an audience and be given a chance to be recognized and appreciated as fine art.

In addition to the more technical chapters in this book, we have included the following two chapters to stimulate an interest in the main principles required to go from visualization to print. These chapters are by no means intended to replace a formal education in photographic art. They will, however, provide some fundamental information and basic guidelines for successful image creation and how to communicate a visual message more clearly. If you are interested in the artistic aspects of image creation beyond what is presented here, please check the bibliography at the end of this book for further reading.

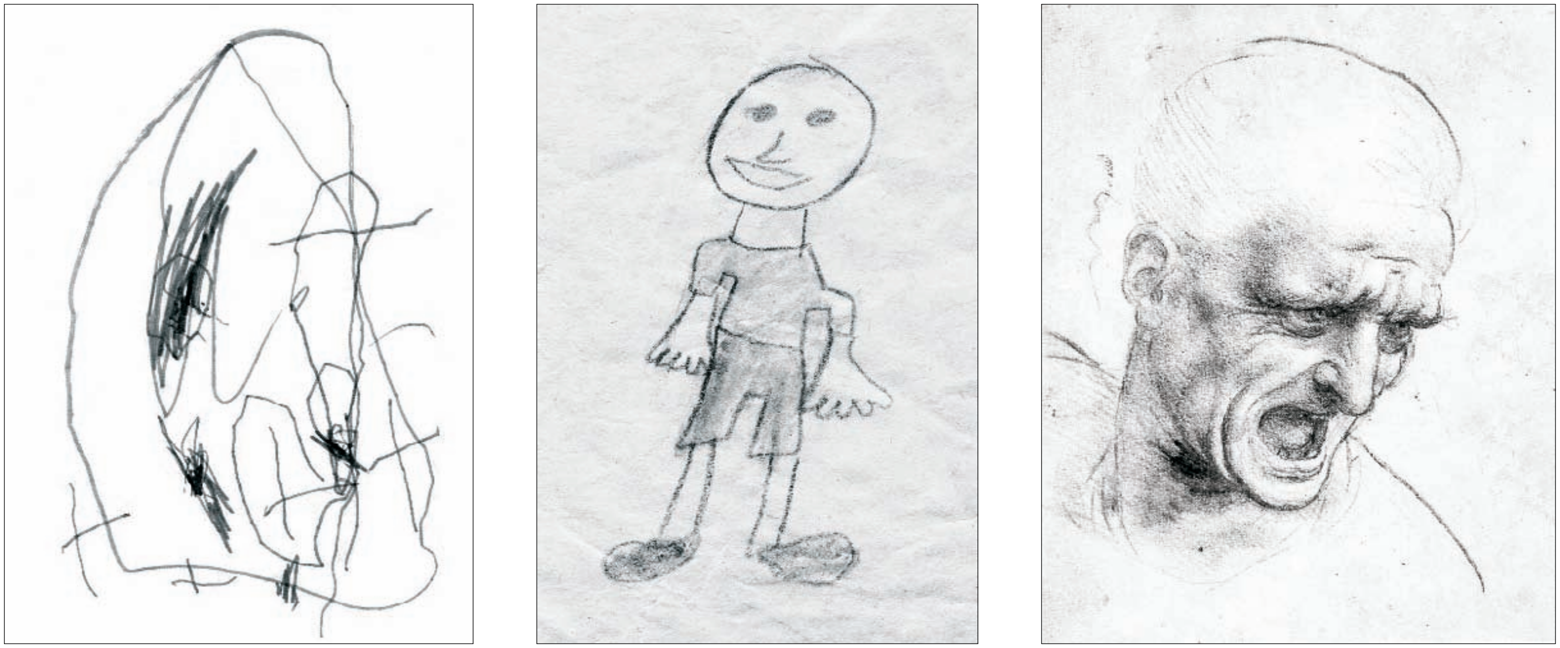
### From Child's Play to Perfection

By the time we reach about two years of age, our mothers trust us enough to not necessarily hurt ourselves every time we pick up a sharp object, and they risk a first attempt of giving us a chance to test our artistic capabilities. In other words, we are presented with a piece of paper and a pencil. The results of these first inexperienced attempts always look very similar to the wild scribbles in fig.1a. These scribbles are evidence of the fact that we have absolutely no control over our tool yet. This first creative achievement and coinciding excitement is limited to drawing a few lines, some chaotic curves and many totally unidentifiable shapes. Nothing more is requested of us at this first productive moment.

Several years later, our technical skills will have improved enough to create identifiable shapes (see fig.1b). Around the age of ten, we can draw a person, tree, animal and many other familiar objects. These sketches are recognizable by other people, but they are far from being realistic images of the world around us. The skill of turning three-dimensional objects and their perspective relationships into realistic two-dimensional representations still requires much improvement of our technical abilities.

Many of the old masters spent a lifetime improving and perfecting their skills. Their ultimate goal was to create life-like images, which could easily be mistaken for the real world. Recent research reveals that even the best of them often used aids, including the camera obscura, to get the perspectives and scale relationships just right. However, this takes little away from our justified admiration for their timeless works

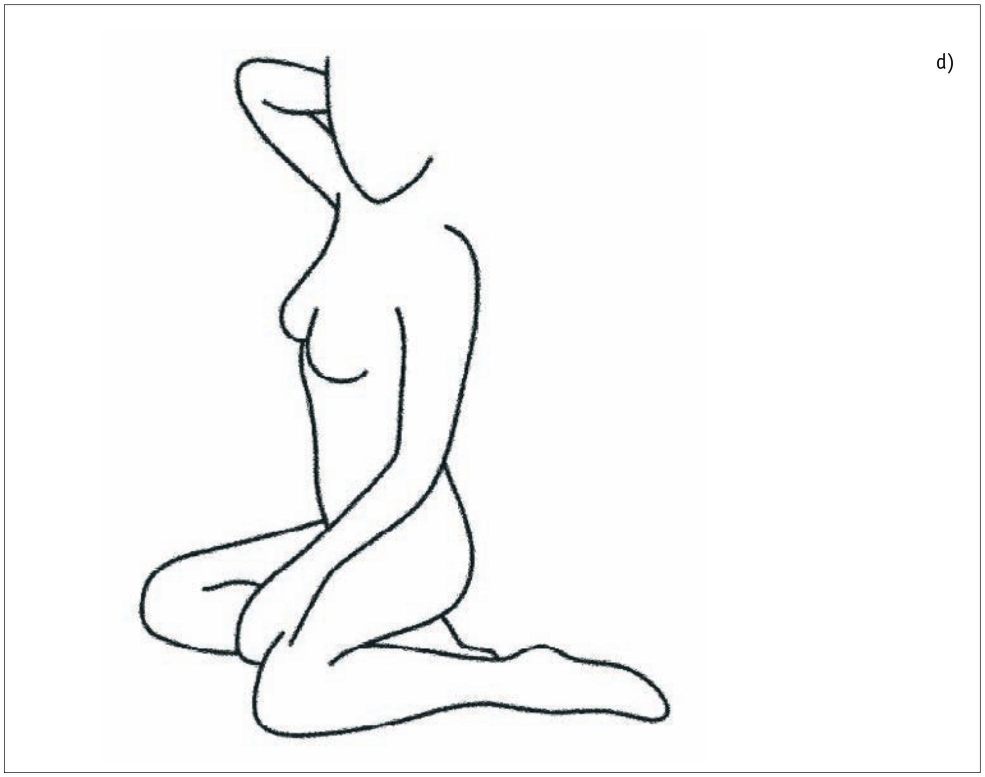
© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50002-8



a)

b)

c)



d)

of art. Fig.1c shows an example of this refined skill in a study by Leonardo da Vinci from around 1505, carried out in black chalk. Few people ever reach this level of perfect craftsmanship, even when devoting their entire lifetimes to learning the required skills. A modern camera can effortlessly capture an image flawlessly within a fraction of a second. Image capture does not equal creative expression. There is more to art than complete control over tools and materials.

Fig.1d shows the sketch of an unknown artist. Its uncluttered simplicity makes it sophisticated. With only a few lines, the artist created an immediately recognizable image. It does not show the technical expertise of Leonardo da Vinci's work, but this artist was in command of the simple tools and materials he had chosen for this work. Would it be any more realistic in its details, the creative sophistication would be lost immediately. Craft and creativity were successfully joined in this image.

fig.1 Painting maturity evolves from immature scribbles (a), to drawing identifiable shapes (b), but rarely reaches the craftsmanship (c) or creativity (d) of the masters.

## From Novice to Photographic Artist

Obviously, as with sketching, drawing and painting, there is also a learning curve and progressive advancement in photography. But thanks to modern equipment and automated photo-lab services, initially, moderate imaging success is easier to come by with a camera than with a pencil or a brush, which explains why it often takes a closer look to detect and appreciate different levels of photographic maturity.

The snap shooter who produced the print in fig.2a was at the beginning of his learning curve. His lack of understanding photographic fundamentals is all too apparent. Composition and focus leave much to be desired. The film was underexposed, leading to ‘empty’ shadows, and overdeveloped, resulting in ‘burned-out’ highlights. This novice had no business shooting a wedding! I’m very sorry and hope they can find it in their hearts to forgive me. This image was taken in 1975, and I stuck to my promise at the time and have not taken a wedding picture since.

The print in fig.2b illustrates a moderate level of photographic expertise. The depth of field is competently controlled, creating an in-focus image, front-to-back. Using the railroad tracks as lead-in lines, to guide the eyes across the image, makes for an effective composition. Accurate exposure and development render all image tones without losing detail, but not enough attention was given to locally optimize tonality or to give the image a clear point of interest. Overall, it is an image executed with reasonable skill, but it is not the work of a darkroom expert. The print is missing tonal depth and sparkle.

Ansel Adams once said that there is very little difference between a good print and a fine print. John Sexton worked for Ansel Adams as his photographic and technical assistant and was a technical consultant for the Ansel Adams Trust. Fig.2c is one example of his own, finely crafted prints. However, one has to see the original print to fully appreciate his darkroom skill. John Sexton spent decades refining his techniques, and he always explores every part of the negative to assemble a convincing image of maximum tonality and clarity. His secret to success is not an arsenal of expensive, high-tech darkroom equipment, but rather decades of experience, a lot of patience and a passion for excellent photographic craftsmanship.

The print in fig.2d, on the other hand, did not require exceptional darkroom skill. Similar to the sketch in fig.1d, it shows a successful image that convinces through its uncluttered simplicity. The photographer demonstrates full command of lighting and composition, and transfers it to a halftone negative, which made it easier to create a print without excessive darkroom manipulation. This image is an effective example of joining competent craft and artistic creativity in a photograph.

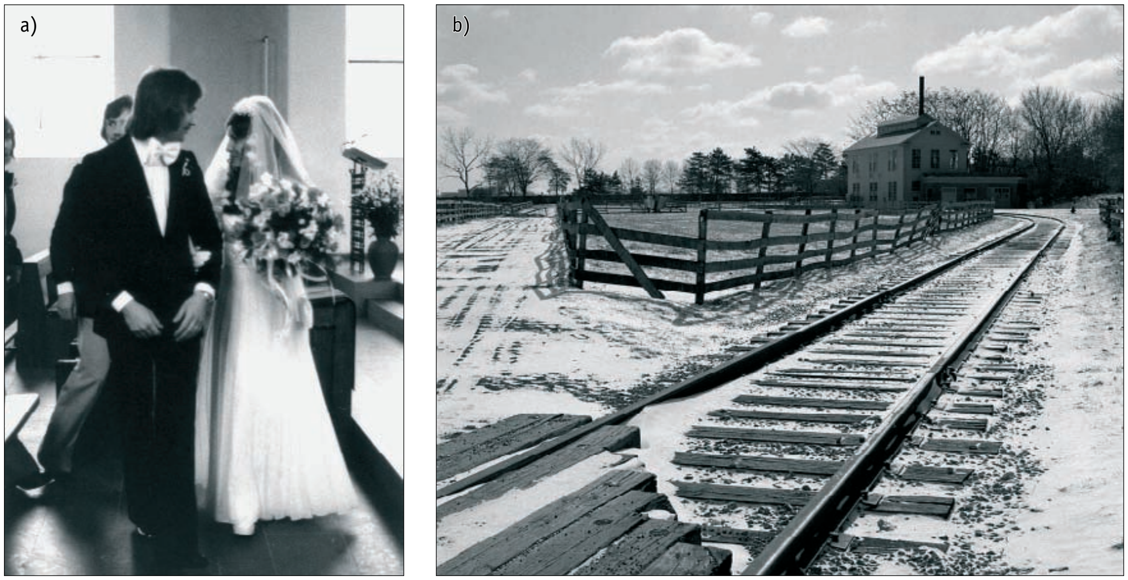


fig.2a-b Photographic maturity evolves not unlike that in sketching or painting. But, with modern equipment, moderate initial imaging success is easier to come by than with a simple pencil, and it takes a closer look to detect and appreciate different levels of photographic maturity. With a little practice and some guidance, a snap shooter (a) can quickly become a competent composer (b), but it takes patience, experience and dedication to master the darkroom and become a photographic artist who consistently creates high-quality images.

fig.2c This print is an example of skilled darkroom work. John Sexton spent decades refining his techniques, and he always explores every part of the negative to assemble a convincing image of maximum tonality and clarity. His secret to success is not an arsenal of expensive, high-tech darkroom equipment, but rather decades of experience, patience and a passion for excellent photographic craftsmanship.

Merced River and Forest, Yosemite Valley, California, © 1983 by John Sexton, all rights reserved

## Are You a Hunter or a Sculptor?

Photographs can be separated into several categories, most commonly classified by the subject matter or the image purpose. The same themes often categorize the photographic artists as well. Consequently, we usually speak of fashion or landscape photographers in an attempt to convey their preferred photographic field. This may help to anticipate what photographic subjects we can expect from their body of work, but it suppresses an easily overlooked, yet fundamental, difference between many successful photographic artists. Some are hunters, and some are sculptors.

A photographic hunter prefers to go after his or her subject. Good examples of photographic hunters are landscape photographers, who travel to interesting places and visit them during the most appropriate season and at the best time of day. For them, image composition is not achieved by moving trees, rivers and mountains, but by a careful selection of viewpoint and camera angle. Landscape photographers may envision a preferred lighting situation, but they do not set it up; instead, they wait for the perfect moment. If it doesn't work out at that very instant, they just wait or return some other time.

A photographic sculptor prefers to model subject and lighting himself. Good examples of photographic sculptors are model or fashion photographers, who prefer to work in the studio. The model is dressed and styled according to image intent, a supporting background is chosen, and the lighting is set up to create the right mood with light and shadow. The time of day or weather condition has no impact on the success of the image.

Hunter or sculptor is not a qualifying distinction of artistic value. One is not more creative than the other, but perhaps, their chosen approaches are the difference between 'visualization' and 'previsualization'. Hunters and sculptors are photographic artists, who create images in different ways. The awareness of your personal preference of one approach over the other will help you along the way to become an artist yourself. Are you a hunter or are you a sculptor?

## The Evolution of an Artist

The sketches and photographs in fig.1 and 2 are examples of how the evolution from crude imagery to fine art evolves in several stages of competency in handling the technical difficulties before creativity has a chance to emerge. This does not allow us to clearly conclude which came first, creativity or craft. Was it the hidden artist, unable to communicate the vision due to the lack of technical competency? Or, was there first a competent craftsman, who was no longer satisfied with technical perfection alone, and finally realized that creativity was the next necessary step? The sequence is irrelevant; only the final level of pictorial maturity is of importance. Ultimately, creative vision and exalted craftsmanship are both characteristics of the person we call 'artist'.

Many people are first attracted to photography by the exciting technology, the lure of sophisticated equipment and the pride of its ownership. They are also intrigued by the challenge of control and enjoy mastering the equipment and materials to achieve technical excellence. Thanks for all that ingenious modern technology, designed to fit hand and eye. There is a great appeal in pressing buttons, clicking precision components into place and testing the latest materials. The results can be judged or enjoyed for their own intrinsic photographic qualities, such as superb detail and rich tones, but we need to avoid falling into the technology trap.

The hesitance to blame initial failures on one's own way of doing things is a common pitfall. The common resistance to making test strips is an excellent example of this aversion. Rather than solving the real issues, there is a tendency to hunt after the latest and greatest inventions. Hoping that the next camera, lens, film, paper or miracle developer and another electronic gadget will fix the problem often only leads to more disappointment. It is far better to thoroughly understand already existing equipment and materials before spending significant amounts of money and endless hours to buy and test new products.

However, even photographers who have honed their skill and achieved the highest level of craftsmanship need to consider making the final step. Tools and materials are vital, of course, and detailed knowledge about using them is absorbing and important, but don't end up shooting photographs just to test out the machinery. Try not to become totally absorbed in the science and craft of photography, which is all too common, but put them into perspective as merely the necessary means to create your own images and eventually reach full pictorial maturity.

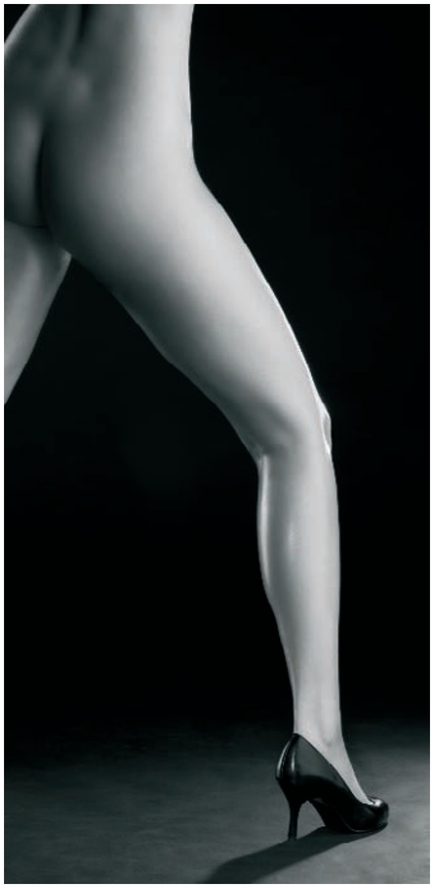


fig.2d This print did not require exceptional darkroom skills. Similar to the sketch in fig.1d, it shows a successful image that convinces through competent lighting, composition and uncluttered simplicity, effectively joining craft and creativity.

# Photographic Quality

## The synergy of image, negative and print quality

Birch Trunks, New Hampshire, © 1984 by John Sexton, all rights reserved

Photographic quality has significantly matured in a variety of ways since its official invention in 1839. Nevertheless, the basic principle of using a negative and positive to create the final image has dominated analog photography since the invention of the Calotype process by William Henry Fox Talbot in 1841.

The Calotype process had the great advantage over the earlier Daguerreotypes that it allowed for multiple copies of the same image, but at the unfortunate cost of inferior print quality. The process used an intermediate paper negative, which was first waxed, to make translucent, before it was contact printed onto sensitized paper to produce the final positive image.

Glass, being almost transparent, would have been a far better material choice for a negative carrier. However, this was not a viable alternative until 1851, when Frederick Scott Archer discovered the means of coating glass sheets with a light-sensitive emulsion, which had to be exposed while still wet. His Collodion wet-plate process was not improved until 1871, when Richard Maddox discovered a way to coat glass plates with a silver emulsion, using gelatin, which resulted in the more convenient dry-plate process.

The invention of celluloid allowed for the introduction of the first flexible film in 1889, and clear polyester polymers eventually replaced celluloid in the 20th century, providing a safe and stable substrate for silver-gelatin emulsions. These and other material advances aside, the fundamentals of creating silver-based images have not changed much since 1841. Modern print quality can be far superior to the humble results at the dawn of photography, if appropriate exposure and processing techniques are applied.

Before we get into the technical details on how to achieve the highest photographic quality with modern materials, let's define what we mean when using words such as image, negative or print quality.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50003-X

> ‘Visualization is based on what is seen, whereas previsualization is based on what is foreseen.’
>
> Keith A. Williams

## Image Quality

The process of achieving photographic quality starts before the technical aspects of photography can be considered. Pointing the camera at the subject without a clear concept for the image is rarely rewarded with success, instead it reduces conscious art to accidental triumph. Image quality is the result of intentional subject selection, careful composition and appropriate lighting, all the while visualizing the final print.

Since the ancient Greeks, philosophers, artists and psychologists have been trying to understand the fundamentals of good design, defining the concepts for the ‘ideal’ and establishing guidelines to separate what works from what does not. They leave us with simple suggestions, such as ‘the rule of thirds’ or ‘the divine proportion’, and more complex visualization concepts, such as the Bauhaus ‘Gestalt Theory’. All of these are worth knowing about, and understanding these principles will enhance conscious artistic skill, but applying design concepts rigidly always conflicts with creative expression. Nevertheless, there are a few characteristics that all successful images have in common. They are the cornerstones of image quality.

1. **Create Impact**
   The combination of basic design principles must create sufficient impact to catch the observer’s attention and get him or her to take a closer look.
2. **Provide Interest**
   Once the observer starts to look, the image must provide attractive and exciting elements to keep him interested in exploring the image further.
3. **Get the Observer Involved**
   A quality image involves the observer and supports his image exploration through guided eye movement and intentional hindrances, inspiring the senses and confirming experiences.

Whether you are a landscape photographer, who is always on the hunt for new and interesting scenery, or a studio photographer planning out the next session and the most appropriate lighting layout, you most likely have already worked, instinctively or intentionally, with the image characteristics mentioned above. However, next time your images are on display, make a point of secretly observing the observers. Find out which of your images have sufficient impact to stop casual viewers dead in their tracks, and which images are barely noticed. Which images hold the observer’s interest for a while, and which do not retain his attention, but send him quickly looking for something more appealing? Attention grabbing images without substance are never good enough. And finally, which images get the longest attention, really inviting the observer to explore the entire image in detail?

At the end of your evaluation, take a look at the most observed images, and try to find out what they have in common, and what makes them so interesting. Compare them to the images that were less noticed, and analyze the difference. This revealing and sobering exercise will not just demonstrate the significance and importance of image quality, but it will also provide many clues on how to improve your images, and guide your photographic development.

## Negative Quality

The first steps towards technical quality are taken during the process of image capture. This involves the selection of the most suitable camera, film and film format, focal length, lens aperture, as well as accurate focus and appropriate depth of field, shutter speed and, potentially, contrast enhancing filters.

It is quite possible to create a decent print from a mediocre negative, employing some darkroom salvaging techniques, but an excellent print can only come from an excellent negative. Aside from focus and adequate depth of field, film exposure and development are the most significant controls of negative quality, and a good negative is one that comes from a properly exposed and developed film.

The photographers of the 19th century were already well aware of the basic influence of exposure and development on negative quality. They knew that the shadow density of a negative is largely controlled by the film exposure, whereas the highlight density depends more on the length of development time. They summed up their experience by creating the basic rules of film exposure and negative process control:

4. **Expose for the Shadows**
   Proper exposure ensures that the shadow areas have received sufficient light to render full detail.
5. **Develop for the Highlights**
   Proper development makes certain that the highlight areas gain tolerable density for the negative to print well on normal grade paper.

> ‘The production of a perfect picture by means of photography is an art. The production of a technically perfect negative is a science.’
>
> Ferdinand Hurter

> 'A fine print is a photograph that meets the highest standards of technical excellence and succeeds in portraying the image visualized by the photographer.'
>
> Ansel Adams

## Print Quality

The printing process is the final step to influence photographic quality. At the printing stage, all image-relevant detail, captured by the negative, must be converted into a positive print, in order to produce a satisfying and convincing image.

To complement the subjective image quality requirements mentioned above, the experienced printer follows a structured and proven printing technique, and makes a selection from available paper choices, which appropriately support the subject and the intended use of the image. Typical selection criteria include, paper thickness, surface texture and the inherent image tone.

In addition, technical print quality involves controlling adequate image sharpness and ensuring the absence of visible imperfections, possibly caused by stray, non-image forming light, or dust and stains. The printer is well advised to make certain that safelights, enlarger, lenses and other printing equipment are kept at peak performance levels.

Nevertheless, subjective print quality is predominantly influenced by print exposure and contrast, which is rarely limited to overall adjustments, but often requires local optimization, including laborious dodging and burning techniques.

Excellent print quality is required to support the visual expression of a valuable photograph. An interesting photograph, well composed and filled with captivating impact, but poorly executed technically, does not do the subject or the photographer justice. A photograph of high technical quality has excellent tonal reproduction throughout the entire tonal range. This includes the following:

6. **Create Brilliant Highlights**
   Specular highlights have no density and are reproduced as pure paper-white, adding brilliance. Diffuse highlights are bright and have a delicate gradation with clear tonal separation, without looking dull or dirty.
7. **Optimize Midtone Contrast**
   There is good separation, due to high local contrast, throughout the midtones, clearly separating them from highlights and shadows.
8. **Protect Detailed Shadows**
   Shadow tones are subtle in contrast and detail, but without getting too dark under the intended lighting conditions. The image includes small areas of deepest paper-black without visible detail, providing a tonal foundation.

Final print quality is subject to every step in the photographic process. In the preparation phase, quality depends on a successful concept, careful composition, and the right selection of negative format, film material, camera equipment and accessories. In the execution phase, quality depends on subject lighting, film exposure, contrast control and the skilled handling of reliable tools. Finally, in the processing phase, a 'perfect' negative is made to create a 'fine' print.

© 2006 by Keith A. Williams, all rights reserved

## Review Questions

1. What is light?
    a. all electromagnetic radiation
    b. the visible part of the electromagnetic spectrum
    c. all radiation including UV and infrared
    d. none of the above

2. What is the principle purpose of the iris?
    a. to see in dim light
    b. to change the depth of focus
    c. to protect the retina from sudden brightness
    d. to improve resolution

3. What is the total sensitivity range of the human eye?
    a. 6 stops
    b. 7 stops
    c. 12 stops
    d. 30 stops

4. What is the typical reading resolution of a healthy adult?
    a. 7 lp/mm
    b. 30 lp/mm
    c. 100 lp/mm
    d. cannot be measured

5. Does the brain improve human vision?
    a. no, it just receives the optical information
    b. yes, it increases resolution through micro tremors
    c. yes, it compensates for variations in brightness
    d. yes, it filters non-visible radiation

6. What do you need to do for a quality negative?
    a. control the exposure as best as you can
    b. just control the development temperature
    c. expose for the highlights and develop for the shadows
    d. expose for the shadows and develop for the highlights

7. What are characteristics of a quality print?
    a. brilliant highlights and detailed shadows
    b. proper shadow exposure
    c. highlights developed until they show detail
    d. nothing but optimized midtone contrast

1b, 2c, 3d, 4a, 5b, 6d, 7a

© 2000 by Chris Woodhouse, all rights reserved

# Fundamental Print Control

This page intentionally left blank

# Timing Print Exposures

## Expose for the highlights

The amount of light reaching a photographic emulsion must be controlled in order to ensure the right exposure. Exposing the film in the camera is typically done with a combination of lens aperture and shutter timing. The lens aperture, also called 'f/stop', controls the light intensity, and the shutter timing, also called 'speed', controls the duration of the exposure. The f/stop settings are designed to either half or double the light intensity. The shutter speed settings are designed to either half or double the exposure duration. This is accomplished by following a geometric series for both aperture and time. The 'film exposure control' table in fig.2 shows an example of typical settings used in modern cameras and lenses. Therefore, an f/stop adjustment in one direction can be offset by a shutter speed adjustment in the opposite direction. Experienced photographers are very comfortable with this convenient method of film exposure control and refer to both, aperture and shutter settings, as f/stops or simply, 'stops'.

In the darkroom, the need for exposure control remains. Splitting this responsibility between the enlarging lens aperture and the darkroom timer is a logical adaptation of the film exposure control. However, the functional requirement for a darkroom timer is different from that of a camera shutter, since the typical timing durations are much longer.

Film exposure durations are normally very short, fractions of a second, where typical enlarging times vary from about 10 to 60 seconds. Long exposure times are best handled with a clock type device which functions as a 'count down'. Some popular mechanical timers, matching this requirement, are available. More accurate, electronic models with additional features are also on the market. Some professional enlargers go as far as featuring a shutter in the light path. This gives an increased accuracy, but is only required for short exposure times.

fig.1 This image of old and worn piping was taken in the Botanical Garden on Belle Isle, just south of Detroit, Michigan USA. The final print exposure and the print manipulation were determined by the f/stop timing method.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50004-1

fig.2 The film exposure is controlled with the taking lens aperture and the shutter timing. Both sequences are geometric and not arithmetic in nature for good reason. The print exposure can be controlled in the same way with the enlarger lens aperture and a darkroom timer.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| arithmetic series<br>a constant difference (here 5) | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
| geometric series<br>a constant ratio (here 2) | 1 | 2 | 4 | 8 | 16 | 32 | 64 |

| film exposure control | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| aperture<br>[f/stop] | 45 | 32 | 22 | 16 | 11 | 8 | 5.6 | 4 | 2.8 | 2 |
| time<br>[1/s] | 500 | 250 | 125 | 60 | 30 | 15 | 8 | 4 | 2 | 1 |

| print exposure control | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| aperture<br>[f/stop] | 45 | 32 | 22 | 16 | 11 | 8 | 5.6 | 4 | 2.8 | 2 |
| time<br>[s] | 1 | 2 | 4 | 8 | 16 | 32 | 64 | 128 | 256 | 512 |

## Arithmetic (Traditional) Timing

A typical traditional printing session is simplified in the following example. The enlarging lens aperture is set to f/8 or f/11 to maximize image quality and allow for reasonable printing times. The printer estimates from experience that the printing time will be around 25 seconds for the chosen enlargement. Typically, a 5 to 7-step test strip, with 5-second intervals, is prepared to evaluate the effect of different exposure times. A sample of such a test strip is shown in fig.3 and was used to test exposures of 10, 15, 20, 25, 30, 35 and 40 seconds. The test strip is then analyzed and the proper exposure time is chosen. In this example, a time of less than 20 seconds would be about right, and the printer may estimate and settle on an exposure time of 18 seconds. Now, a so-called 'base exposure' time is established. This sequence may be repeated for different areas of interest, for example textured highlights and open shadows. If they deviate from the base exposure, dodging and burning may be required to optimize exposure locally.

fig.3 (right)
a traditional test strip in 5-s increments (arithmetic series)

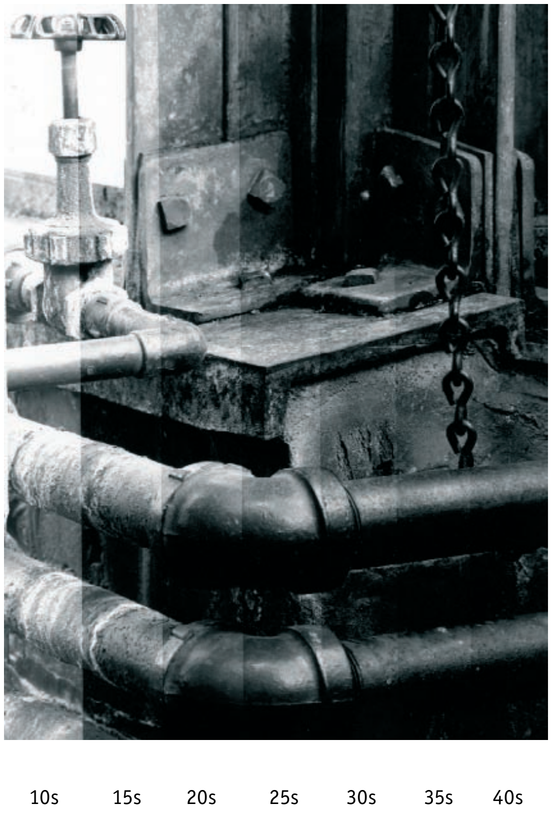
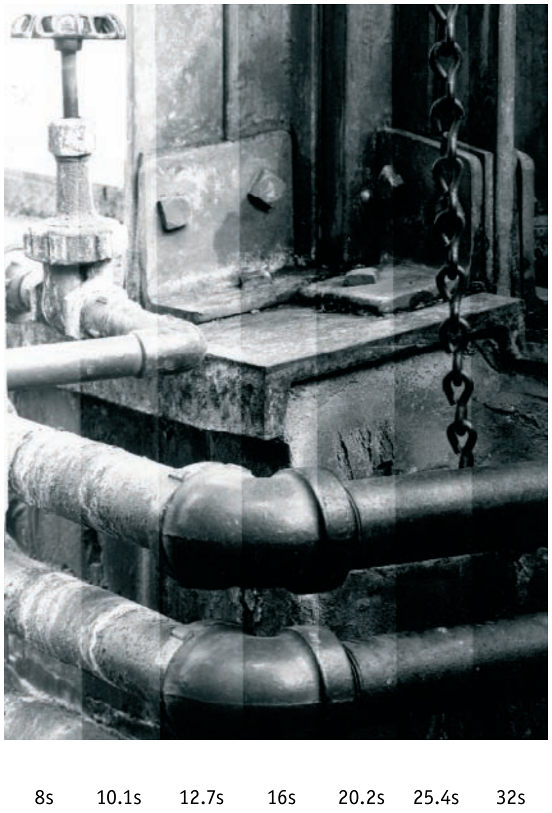


fig.4 (far right)
an f/stop test strip in 1/3-stop increments (geometric series)



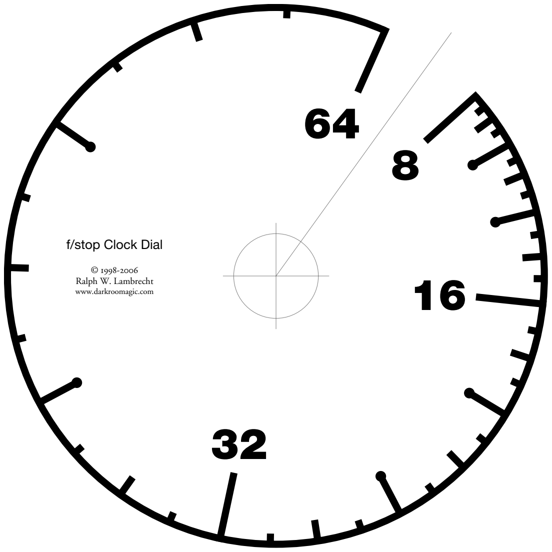


fig.5a (far left) A simple analog f/stop dial, from 8 to 64 seconds in 1/3, 1/6 and 1/12-stop increments, can be made and attached to any analog timer.

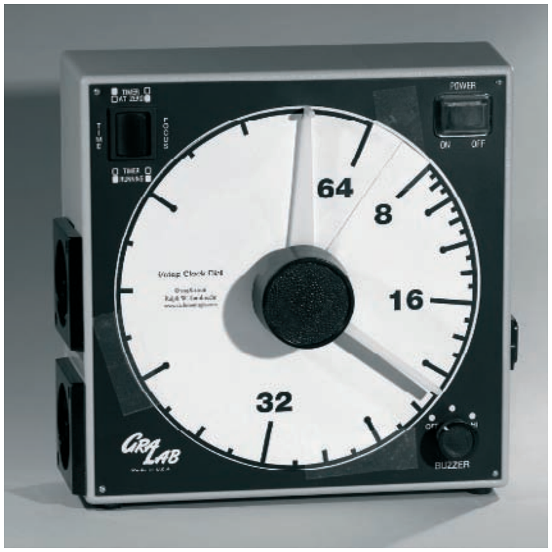


fig.5b (left) Here the f/stop clock dial was enlarged and temporarily taped to an already existing 'GraLab 300' timer.

This is a reasonable approach to printing, but it does not utilize some of the benefits of geometric, or f/stop timing. In the traditional, arithmetic timing method, uniform time increments produce unequal changes of exposure. As seen in fig.3, the difference between the first two steps is 1/2 stop, or 50%. However, the difference between the last two steps is only 14%, or slightly more than a 1/6 stop. Therefore, arithmetic timing methods provide too great of a difference in the light steps and too little of a difference in the dark steps of a test strip. This makes it difficult to estimate an accurate base exposure time for the print.

## Geometric (f/stop) Timing

My involvement with geometric printing began when I met a fellow photographer and printer in the UK. He convinced me to give it a try. It did not take long to realize the major benefits of this very logical technique. After a small learning curve and the typical discomfort with any unfamiliar technique, geometric timing has now become the standard in my darkroom. It provides any darkroom practitioner with robust print control and the ability to predict repeatable results with confidence. I will explain the benefits of geometric timing in the chronological order of a typical printing session from the test strip, through the exposure adjustment for a work print, to the fine tuning with dodging and burning, but first some general notes.

Considering the typical design of darkroom timers, it is understandable why arithmetic timing has been the predominant method of exposing photographic paper. Nevertheless, it is worth considering geometric timing not just for film exposure but also for print exposure, because it has significant advantages when it comes to test strips, print control, repeatability and record keeping. Since lens aperture markings also follow a geometric progression, geometric timing is often referred to as 'f/stop timing'.

Fig.5 provides an analog version of an f/stop timing sequence, which helps to illustrate the effect. It is a continuation of the well-known camera shutter speed doublings from 8 up to 64 seconds, and it is subdivided first into 1/3 then 1/6 and finally 1/12 stop. These ranges were selected because times below 8 seconds are difficult to control with an analog timer, and times well above one minute are too time consuming for a practical darkroom session. Increments down to 1/12 stop are used, because that is about the smallest appreciable exposure increment. Anything less is really hard to make out. For normal paper grades, between grade 2 and 3, enlarging time differences of a 1/3 stop (~20%) are significant in tonal value, 1/6 stop (~10%) can easily be seen and differences of a 1/12 stop (~5%) are minute, but still clearly visible, if viewed next to each other. Smaller increments may be of use for paper grades 4 and 5 but are rarely required. The analog dial clearly shows how f/stop timing fractions increase with printing time. Fixed increments of time have a larger

| dodging [f/stop] ← | | | | | | base exposure | → burning [f/stop] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -1 | -⅚ | -⅔ | -½ | -⅓ | -⅙ | | +⅙ | +⅓ | +½ | +⅔ | +⅚ | +1 | +1⅓ | +1⅔ | +2 | +2⅓ | +2⅔ | +3 |
| -4.0 | -3.5 | -3.0 | -2.3 | -1.7 | -0.9 | 8 | 1.0 | 2.1 | 3.3 | 4.7 | 6.3 | 8.0 | 12.2 | 17.4 | 24.0 | 32.3 | 42.8 | 56.0 |
| -4.2 | -3.7 | -3.1 | -2.5 | -1.7 | -0.9 | 8.5 | 1.0 | 2.2 | 3.5 | 5.0 | 6.6 | 8.5 | 12.9 | 18.4 | 25.4 | 34.2 | 45.3 | 59.3 |
| -4.5 | -3.9 | -3.3 | -2.6 | -1.9 | -1.0 | 9.0 | 1.1 | 2.3 | 3.7 | 5.3 | 7.0 | 9.0 | 13.6 | 19.5 | 26.9 | 36.3 | 48.0 | 62.9 |
| -4.8 | -4.2 | -3.5 | -2.8 | -2.0 | -1.0 | 9.5 | 1.2 | 2.5 | 3.9 | 5.6 | 7.4 | 9.5 | 14.5 | 20.7 | 28.5 | 38.4 | 50.9 | 66.6 |
| -5.0 | -4.4 | -3.7 | -3.0 | -2.1 | -1.1 | 10.1 | 1.2 | 2.6 | 4.2 | 5.9 | 7.9 | 10.1 | 15.3 | 21.9 | 30.2 | 40.7 | 53.9 | 70.6 |
| -5.3 | -4.7 | -4.0 | -3.1 | -2.2 | -1.2 | 10.7 | 1.3 | 2.8 | 4.4 | 6.3 | 8.3 | 10.7 | 16.2 | 23.2 | 32.0 | 43.1 | 57.1 | 74.8 |
| -5.7 | -5.0 | -4.2 | -3.3 | -2.3 | -1.2 | 11.3 | 1.4 | 2.9 | 4.7 | 6.6 | 8.8 | 11.3 | 17.2 | 24.6 | 33.9 | 45.7 | 60.5 | 79.2 |
| -6.0 | -5.3 | -4.4 | -3.5 | -2.5 | -1.3 | 12.0 | 1.5 | 3.1 | 5.0 | 7.0 | 9.4 | 12.0 | 18.2 | 26.1 | 36.0 | 48.4 | 64.1 | 83.9 |
| -6.3 | -5.6 | -4.7 | -3.7 | -2.6 | -1.4 | 12.7 | 1.6 | 3.3 | 5.3 | 7.5 | 9.9 | 12.7 | 19.3 | 27.6 | 38.1 | 51.3 | 67.9 | 88.9 |
| -6.7 | -5.9 | -5.0 | -3.9 | -2.8 | -1.5 | 13.5 | 1.6 | 3.5 | 5.6 | 7.9 | 10.5 | 13.5 | 20.4 | 29.3 | 40.4 | 54.4 | 72.0 | 94.2 |
| -7.1 | -6.3 | -5.3 | -4.2 | -2.9 | -1.6 | 14.3 | 1.7 | 3.7 | 5.9 | 8.4 | 11.1 | 14.3 | 21.7 | 31.0 | 42.8 | 57.6 | 76.3 | 99.8 |
| -7.6 | -6.6 | -5.6 | -4.4 | -3.1 | -1.6 | 15.1 | 1.8 | 3.9 | 6.3 | 8.9 | 11.8 | 15.1 | 23.0 | 32.8 | 45.3 | 61.0 | 80.8 | 106 |
| -8.0 | -7.0 | -5.9 | -4.7 | -3.3 | -1.7 | 16 | 2.0 | 4.2 | 6.6 | 9.4 | 12.5 | 16.0 | 24.3 | 34.8 | 48.0 | 64.6 | 85.6 | 112 |
| -8.5 | -7.4 | -6.3 | -5.0 | -3.5 | -1.8 | 17.0 | 2.1 | 4.4 | 7.0 | 10.0 | 13.3 | 17.0 | 25.8 | 36.9 | 50.9 | 68.5 | 90.7 | 119 |
| -9.0 | -7.9 | -6.6 | -5.3 | -3.7 | -2.0 | 18.0 | 2.2 | 4.7 | 7.4 | 10.5 | 14.0 | 18.0 | 27.3 | 39.1 | 53.9 | 72.6 | 96.1 | 126 |
| -9.5 | -8.3 | -7.0 | -5.6 | -3.9 | -2.1 | 19.0 | 2.3 | 4.9 | 7.9 | 11.2 | 14.9 | 19.0 | 28.9 | 41.4 | 57.1 | 76.9 | 102 | 133 |
| -10.1 | -8.8 | -7.5 | -5.9 | -4.2 | -2.2 | 20.2 | 2.5 | 5.2 | 8.4 | 11.8 | 15.8 | 20.2 | 30.6 | 43.8 | 60.5 | 81.4 | 108 | 141 |
| -10.7 | -9.4 | -7.9 | -6.3 | -4.4 | -2.3 | 21.4 | 2.6 | 5.6 | 8.8 | 12.5 | 16.7 | 21.4 | 32.5 | 46.4 | 64.1 | 86.3 | 114 | 150 |
| -11.3 | -9.9 | -8.4 | -6.6 | -4.7 | -2.5 | 22.6 | 2.8 | 5.9 | 9.4 | 13.3 | 17.7 | 22.6 | 34.4 | 49.2 | 67.9 | 91.4 | 121 | 158 |
| -12.0 | -10.5 | -8.9 | -7.0 | -4.9 | -2.6 | 24.0 | 2.9 | 6.2 | 9.9 | 14.1 | 18.7 | 24.0 | 36.4 | 52.1 | 71.9 | 96.8 | 128 | 168 |
| -12.7 | -11.1 | -9.4 | -7.4 | -5.2 | -2.8 | 25.4 | 3.1 | 6.6 | 10.5 | 14.9 | 19.9 | 25.4 | 38.6 | 55.2 | 76.2 | 103 | 136 | 178 |
| -13.5 | -11.8 | -10.0 | -7.9 | -5.6 | -2.9 | 26.9 | 3.3 | 7.0 | 11.1 | 15.8 | 21.0 | 26.9 | 40.9 | 58.5 | 80.7 | 109 | 144 | 188 |
| -14.3 | -12.5 | -10.5 | -8.4 | -5.9 | -3.1 | 28.5 | 3.5 | 7.4 | 11.8 | 16.7 | 22.3 | 28.5 | 43.3 | 62.0 | 85.5 | 115 | 153 | 200 |
| -15.1 | -13.3 | -11.2 | -8.8 | -6.2 | -3.3 | 30.2 | 3.7 | 7.9 | 12.5 | 17.7 | 23.6 | 30.2 | 45.9 | 65.7 | 90.6 | 122 | 162 | 211 |
| -16.0 | -14.0 | -11.8 | -9.4 | -6.6 | -3.5 | 32 | 3.9 | 8.3 | 13.3 | 18.8 | 25.0 | 32.0 | 48.6 | 69.6 | 96.0 | 129 | 171 | 224 |
| -17.0 | -14.9 | -12.5 | -9.9 | -7.0 | -3.7 | 33.9 | 4.2 | 8.8 | 14.0 | 19.9 | 26.5 | 33.9 | 51.5 | 73.7 | 102 | 137 | 181 | 237 |
| -18.0 | -15.8 | -13.3 | -10.5 | -7.4 | -3.9 | 35.9 | 4.4 | 9.3 | 14.9 | 21.1 | 28.1 | 35.9 | 54.6 | 78.1 | 108 | 145 | 192 | 251 |
| -19.0 | -16.7 | -14.1 | -11.1 | -7.9 | -4.2 | 38.1 | 4.7 | 9.9 | 15.8 | 22.4 | 29.8 | 38.1 | 57.8 | 82.8 | 114 | 154 | 204 | 266 |
| -20.2 | -17.7 | -14.9 | -11.8 | -8.3 | -4.4 | 40.3 | 4.9 | 10.5 | 16.7 | 23.7 | 31.5 | 40.3 | 61.3 | 87.7 | 121 | 163 | 216 | 282 |
| -21.4 | -18.7 | -15.8 | -12.5 | -8.8 | -4.7 | 42.7 | 5.2 | 11.1 | 17.7 | 25.1 | 33.4 | 42.7 | 64.9 | 92.9 | 128 | 173 | 229 | 299 |
| -22.6 | -19.9 | -16.7 | -13.3 | -9.3 | -4.9 | 45.3 | 5.5 | 11.8 | 18.7 | 26.6 | 35.4 | 45.3 | 68.8 | 98.4 | 136 | 183 | 242 | 317 |
| -24.0 | -21.0 | -17.7 | -14.0 | -9.9 | -5.2 | 47.9 | 5.9 | 12.5 | 19.9 | 28.2 | 37.5 | 47.9 | 72.9 | 104 | 144 | 194 | 256 | 336 |
| -25.4 | -22.3 | -18.8 | -14.9 | -10.5 | -5.5 | 50.8 | 6.2 | 13.2 | 21.0 | 29.8 | 39.7 | 50.8 | 77.2 | 110 | 152 | 205 | 272 | 356 |
| -26.9 | -23.6 | -19.9 | -15.8 | -11.1 | -5.9 | 53.8 | 6.6 | 14.0 | 22.3 | 31.6 | 42.1 | 53.8 | 81.8 | 117 | 161 | 217 | 288 | 377 |
| -28.5 | -25.0 | -21.1 | -16.7 | -11.8 | -6.2 | 57.0 | 7.0 | 14.8 | 23.6 | 33.5 | 44.6 | 57.0 | 86.7 | 124 | 171 | 230 | 305 | 399 |
| -30.2 | -26.5 | -22.4 | -17.7 | -12.5 | -6.6 | 60.4 | 7.4 | 15.7 | 25.0 | 35.5 | 47.2 | 60.4 | 91.8 | 131 | 181 | 244 | 323 | 423 |
| -32.0 | -28.1 | -23.7 | -18.7 | -13.2 | -7.0 | 64 | 7.8 | 16.6 | 26.5 | 37.6 | 50.0 | 64.0 | 97.3 | 139 | 192 | 259 | 342 | 448 |

fig.6 The f/stop timing table, including adjustments for dodging and burning. Determine the base print exposure time, rendering significant print highlights to your satisfaction, and find this 'base exposure' in the center column. Base exposure times are listed in 1 stop (black), 1/3 stop (dark gray), 1/6 stop (light gray) and 1/12 stop increments. After adjusting overall print contrast, rendering significant print shadows as desired, find related dodging and burning times in 1/6 stop increments left and right to the base exposure to fine-tune the print.

Example: Assuming a base exposure time of 19.0s, exposure is held back locally for 2.1s to dodge an area for a 1/6 stop, and a 4.9s exposure is added locally to apply a 1/3 stop burn-in. Base exposure time and f/stop modifications are entered into the print record for future use. The exposure time must be modified if print parameters or materials change, but dodging and burning is relative to the exposure time, and consequently, the f/stop modifications are consistent.

effect on short exposure times and a smaller effect on long exposure times.

The numerical f/stop timing table in fig.6 is a more convenient way to determine precise printing times than the previous analog table. It also includes dodging and burning times as small as 1/6-stop increments. It can be used with any darkroom timer, but a larger version may be required to see it clearly in the dark. Base exposure times are selected from the timing table and all deviations are recorded in stops, or fractions thereof. This is done for test strips, work prints and all fine-tuning of the final print, including the dodging and burning operations. Now, let's get started.

### 1. The Test Strip

Assuming a typical printing session, select the following timing steps in 1/3-stop increments from the timing table: 8, 10.1, 12.7, 16, 20.2, 25.4 and 32 seconds. The resulting test strip is shown in fig.4. Please note that the range of exposure time is almost identical to the arithmetic test strip. However, a comparison between the two test strips reveals that the geometrically spaced f/stop version is much easier to interpret. There is more separation in the light areas and still clear differences in the dark areas of the test strip. After evaluation of the test strip, it can be determined that the right exposure time must be between 16 and 20.2 seconds. A center value of 18.0 seconds may be selected, or another test strip with finer increments may be prepared.

### 2. The Work Print

The next step is to create a well-exposed work print, at full size and exposed at the optimum base time. This base time is usually the right exposure time to render the textured highlights at the desired tonal value. In this example, the first full sheet was exposed at 18.0 seconds, developed and evaluated. I found this print just slightly too light and decided to increase the exposure by a 1/12 stop to 19.0 seconds, knowing that this would darken the print only marginally. I ended up with the almost same result as in the traditional timing method, but this time with much more confidence and control.

In a typical printing session, the print contrast would now be adjusted to render the important shadows at the desired tonal values, but this is covered in the next chapter. To simplify things for now, I will, therefore, assume that we already have the proper print contrast at grade 2. Consequently, we have at present a well-exposed work print with a base print exposure time of 19.0 seconds and good overall print contrast. A work print like this is the necessary foundation to successfully plan all subsequent print manipulations, with the intention to further optimize the image.

#### 3. Dodging and Burning

Fine-tuning all of the tonal values, through dodging and burning, only takes place once the right base image exposure and good overall contrast have been found. I recommend to test strip the desired exposure times for all other areas of importance within the image and then to record them all as deviations from the base exposure time in units of f/stop fractions. The table in fig.6 provides dodging and burning times in relation to several base times.

In this case, I found it advantageous to dodge the center of the print for a 1/6 stop, or as read from the table, for the last 2.1 seconds of the base exposure time and recorded it as (-1/6) on a printing map. The final printing map is shown in fig.7 for your reference. A stubborn upper left hand corner needed an additional 1-stop burn-in (+1) to reveal the first light gray. According to the table, this was equivalent to 19.0 seconds. The top, left and right edges needed an additional 1/3 stop (+1/3) and the timer was set to 4.9 seconds to achieve that exposure. A minor adjustment for the bottom edge of 1/6 stop (+1/6) concluded the session, and the lead picture shows the final image.

The final printing map will be stored with the negative and can be used for future enlarging at any scale. A new base exposure time must be found, when a new enlarging scale becomes necessary, but the f/stop differences for dodging and burning always remain the same. This printing map will also remain useful even if materials for paper, filters and chemicals have been replaced or have aged. It will also be easier to turn excessive burn-in times into shorter times at larger lens apertures in order to avoid reciprocity failures.

Traditional printing has standard edge-burning times, such as 3 seconds, as an example. This can be a relatively large amount for a small print with short base exposure times, and it can be a very short time for a large print with a relatively long base exposure time. Adding a 1/3 stop to the edges is a far more consistent way to work.

Some experienced printers have adopted the practice of using percentages of the base exposure time for all dodging and burning procedures. This approach is not as consistent but very similar to f/stop timing, and these printers should have little or no trouble switching to f/stop printing, because they are already halfway there.

## Hardware Requirements

You do not need any additional equipment to give f/stop timing a try. With the tables provided in this chapter and your current darkroom setup, you have everything needed to get started with this logical way to print. Any timer can be controlled to perform f/stop timing, especially when the exposure times are longer than 20 seconds.

Nevertheless, if you do not have a decent darkroom timer yet and if your budget allows, then go out and trade a bit of money for a lot of convenience and time saved, by investing in a good f/stop timer. There are only a few electronic f/stop timers available on the market. They usually provide f/stop and linear timing with a digital display. Some come with memory features to record the sequence of a more involved printing session.

## Conclusion

In this chapter, it was shown that altering the print exposure time in an f/stop sequence is a logical adaptation of film exposure control. You are using it with your camera because it works. Why not use it in the darkroom too?

Two significant advantages are obvious. First, test strips become more meaningful, with even exposure increments between the strips, which allow straightforward analysis at any time, aperture or magnification setting. Second, printing records can be used for different paper sizes and materials without a change. After a little experience with the technique, it becomes second nature to visualize the effect of, say, a 1/3-stop print exposure, without worrying about the actual time. This is particularly useful for burning down critical areas or when working at different magnifications and apertures. Several well-known printers record image exposures in f/stops to describe their printing maps. Using f/stop timing makes printing easier, more flexible, and simpler to create meaningful printing records for future darkroom sessions.

f/stop timing has several advantages over traditional timing.

1. test strips have even exposure increments
2. straightforward test analysis at any time, aperture or magnification setting
3. print records are independent of equipment or materials

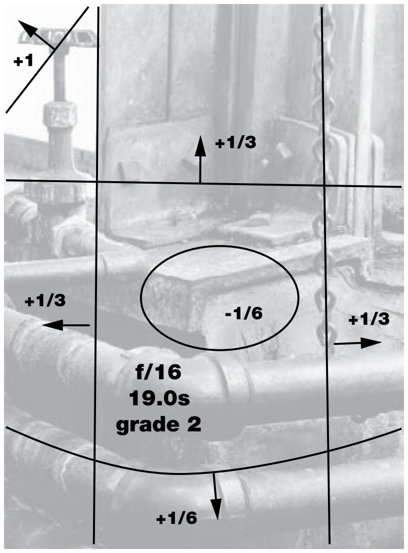


fig.7 Dodging and burning is recorded in f/stop deviations on the printing map. This map is stored with the negative for future enlarging at any scale.

# Paper and Print Contrast

## Control the shadows with contrast

Print contrast is the optical density difference between the highlights and the shadows of a photographic print. In other words, the brighter the highlights and the darker the shadows, the higher the overall print contrast. Since highlight density is most effectively controlled through print exposure, shadow density is best controlled by adjusting print contrast. To make this effort possible, most photographic papers are manufactured in various grades of paper contrast.

Tailoring print contrast by selecting the appropriate paper contrast does not just compensate for less than ideally exposed or developed negatives, but it also accommodates different subject brightness ranges, and it can ingeniously facilitate creativity. After selecting the proper print exposure for the highlights, correctly pairing paper and negative contrast is the second step towards optimizing a print's appearance. A high-contrast negative must be equivalently compensated with a low-contrast paper and vice versa, otherwise shadows will be too dark and hide important detail, or they will be too flat and leave the whole print without punch. But before selecting the right paper contrast, the practitioner must first choose between fixed- or variable-contrast papers.

### Fixed-Contrast Paper

Some photographic papers are still offered as fixed-contrast papers. These more traditional papers come in up to six grades, numbered from '0' to '5' to identify the paper's approximate contrast, with increasing numbers symbolizing increasing contrast (see fig.1). Grade 2 is the 'normal' or medium-contrast paper, and is ideally suited for medium-contrast negatives. Soft papers, grade 0 and 1, produce low-contrast prints from medium-contrast negatives and medium-contrast prints from high-contrast negatives. Hard papers, grade 3 to 5, produce medium-contrast prints

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50005-3

from low-contrast negatives and high-contrast prints from medium-contrast negatives. For economic reasons, many fixed-contrast papers are only obtainable in two or three grades, with availability focusing on the more popular grades 1 to 3. What follows is a brief applicability guide to using fixed-contrast papers:

**Grade 0** (very soft): This extra low-contrast paper is used for negatives with excessively high-contrast or to create special low-contrast effects.
**Grade 1** (soft): A well exposed but overdeveloped negative, or a negative of a high-contrast scene will print well on this low-contrast paper.
**Grade 2** (medium): A well exposed and developed negative of a normal scene with an average subject brightness range will print well on this medium-contrast paper.
**Grade 3** (hard): A slightly underexposed or underdeveloped negative, or a negative of a low-contrast scene, will print well on this higher-contrast paper. Some consider this to be their normal grade.
**Grade 4** (very hard): An underexposed and underdeveloped negative, or a negative of a very low-contrast scene, will print best on this paper.
**Grade 5** (extra hard): This extra high-contrast paper is used for negatives with extremely low-contrast or to create special high-contrast effects.

Unfortunately, paper manufacturers never agreed on a standard for these numeric values. A grade-2 paper made by one manufacturer may have as much, or more, contrast than a grade-3 paper made by another. Paper contrast may also vary between different papers from the same manufacturer. One can only rely on the fact that a higher number of the same paper will give more contrast, while a lower number will give less.

Experienced printers, specializing in only one type of subject and exercising tight process control, may get away with keeping just one or two grades in stock. Others may have to have all grades at hand in order to be prepared for varying negative contrast needs. The contrast of fixed-contrast papers can be modified within reason by using special developers and other darkroom techniques, but essentially, and as the name implies, the contrast for these papers is fixed. This fact may evolve to a significant hurdle for the discriminating printer, when it comes to fine-tuning print contrast in order to optimize print quality.

(image © 1998 by Paul Kessel, all rights reserved)

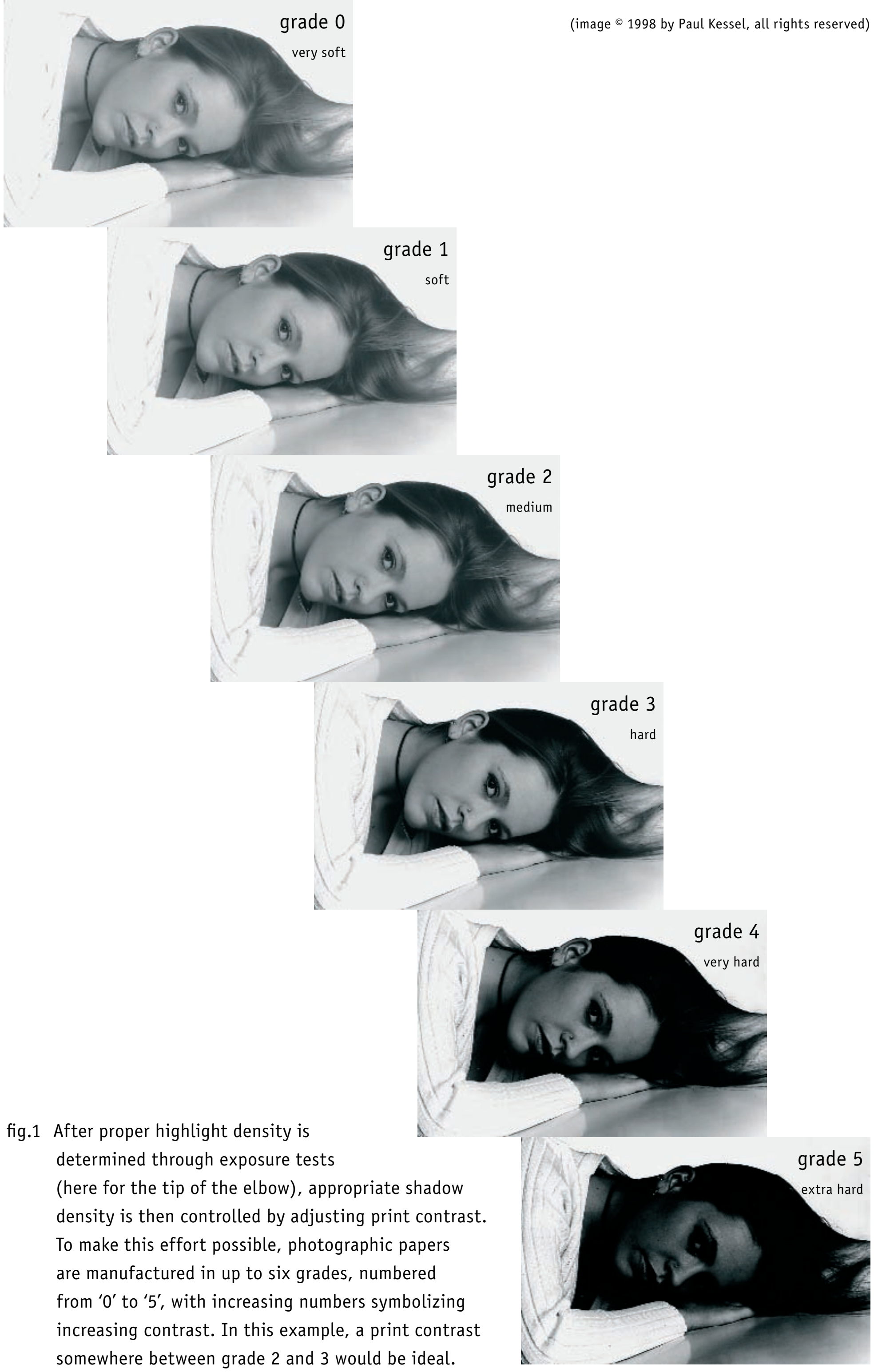


fig.1 After proper highlight density is determined through exposure tests (here for the tip of the elbow), appropriate shadow density is then controlled by adjusting print contrast. To make this effort possible, photographic papers are manufactured in up to six grades, numbered from ‘0’ to ‘5’, with increasing numbers symbolizing increasing contrast. In this example, a print contrast somewhere between grade 2 and 3 would be ideal.

## Variable-Contrast (VC) Paper

Most papers offered today are only available as variable-contrast papers. These papers are coated with a mixture of two or three separate emulsions. All components of the mixed emulsion are sensitive to blue light but vary in sensitivity to green light. When variable-contrast papers are exposed to blue light, all components react and contribute similarly to the final image. This creates a high-contrast image because of the immediate additive density effect produced by the different components. On the other hand, when variable-contrast papers are exposed to green light, only the highly green-sensitive component reacts initially, while the other components contribute with increasing green-light intensity. This creates a low-contrast image because of the delayed additive density effect produced by the different components. By varying the ratio of blue to green light exposure, any and every intermediate paper contrast from ‘very soft’ to ‘extra hard’ can be obtained within the same sheet of paper. This offers tremendous flexibility, enhanced technical control and new creative opportunities.

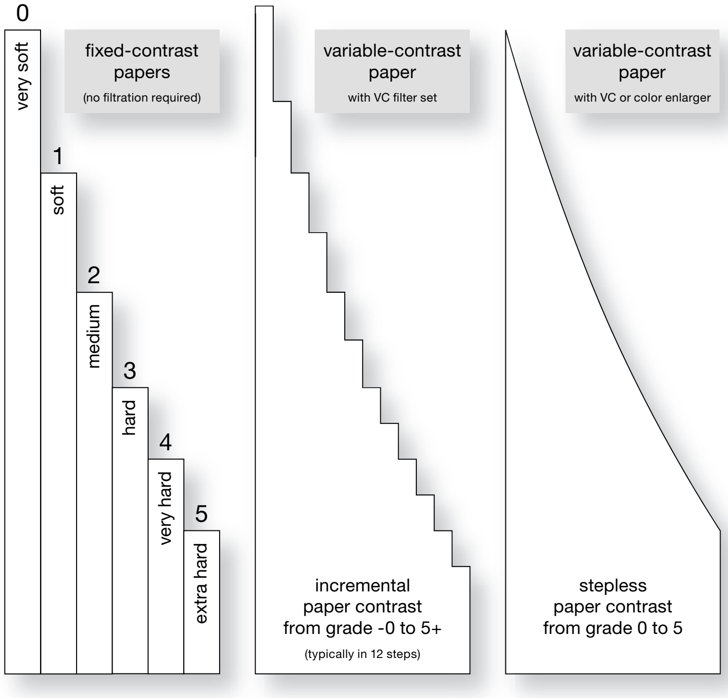


fig.2 The contrast of fixed-contrast papers can be modified with special developers or darkroom techniques but is essentially fixed with relatively rough increments (left). This can be a significant hurdle when it comes to fine-tuning print contrast and optimizing print quality. The contrast spacing of variable-contrast paper is much smoother, when used with filter sets (middle), and totally stepless contrast changes can be obtained with color or VC enlargers (right).

The task of controlling the blue-to-green light ratio can be achieved through several methods. The simplest system is a set of twelve specially designed filters, which are available from most major paper manufacturers. These sets approximate the traditional contrast grades from ‘0’ to ‘5’, in 1/2-grade increments and often offer one extra filter, extending the contrast range even further. Another, more sophisticated, approach is to calibrate a color enlarger, utilizing the yellow and magenta filter adjustments, or to use a purpose-built variable-contrast enlarger head. Fig.2 illustrates the relatively rough contrast spacing of fixed-contrast paper (left). The contrast spacing of variable-contrast paper is much smoother, when used with filter sets (middle), and totally stepless contrast changes can be obtained with color or VC enlargers (right). The practical application of variable-contrast papers is shown throughout the rest of the book, but for more detailed technical information, see the first few chapters in ‘Advanced Print Control’.

The proponents of fixed-contrast papers claim for them to offer superior image quality. This was certainly true decades ago, when variable-contrast papers were still going through significant technical development and improvements. Today, this claim is hard to substantiate. The proponents of variable-contrast papers claim to save money by not having to buy several boxes of paper, while also reducing darkroom complexity and inventory. Cost reduction is an odd argument for variable-contrast papers, since the cost of paper purely depends on the number of sheets used. However, the initial investment and the darkroom complexity is indeed less, since one can get all grades from only one box of paper. In addition, as paper does degrade over time, it is a benefit to quickly work through a box of paper and replenish it with fresh materials, rather than frequently being left with outdated sheets of the less popular grades.

Considering the overwhelming benefits, it is hardly a surprise that variable-contrast papers are by far the most popular choice to optimize image contrast and create high-quality prints. The advantages of variable contrast paper over graded paper have made it the prime choice for many photographers today. The ability to get all paper grades from one box of paper, and even one sheet, has reduced darkroom complexity and provided creative controls not otherwise available with graded papers.

# Basics of Photographic Printing

## A fundamental but thorough approach

The students of my photography class and I had started our second day in the darkroom. We had just developed contact sheets from previously processed film and were about to select a negative to learn basic photographic printing. The negative I proposed had never been printed before, and therefore, it was a bit of an experience for all of us. Most instructors shy away from using a 'new' negative in this situation. They feel that exploring the potential of a negative and teaching basic printing at the same time may conflict. It may also generate confusion and may lose the educational value, which comes with a prepared and well-organized session. I cannot disagree with that viewpoint, but I feel confident enough to believe that a structured operating sequence will tackle any negative. This particular negative did not seem to contain any unusual challenges.

Photographic printing is primarily art and only secondarily science. Turning the negative film image into a well-balanced positive print, with a full range of tones and compelling contrast, can be time-consuming and occasionally frustrating, unless a well thought-out printing sequence is considered. Optimizing a print by trial and error is rarely satisfying and often leads to only mediocre results. A structured printing technique, on the other hand, will quickly reveal the potential of a negative. The method described here is a valuable technique for beginning and more experienced printers alike, and with individual modifications, it is used by many printers today. I have been taught this structured technique by master printers such as John Sexton and Howard Bond, who use it themselves. It works well in almost all cases but should be viewed as, and understood to be, a guideline and not a law. Use the technique to get started, but feel free to modify it, in order to develop your personal printing style.

The picture was taken in downtown Detroit at the old and abandoned railway station, which once was a beautiful example of early 20th century architecture. Unfortunately, it is now a ruin, fenced in and boarded up to prevent unwanted entrance. The city of Detroit

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50006-5

is concerned about the structural integrity of the building. Nonetheless, it is refuge to some homeless people. The inside of the building shows clear signs of vandalism and decades of decay, but the former beauty is still visible to the trained photographic eye. The image was taken with a Hasselblad 501C and a Carl Zeiss Planar 2.8/80 at f/11 with an exposure time of 1/2 second on TMax-100. It was then developed normally in Xtol 1+1 for 8 minutes.

Before we get started, let me share my thoughts about electronic darkroom aids. I use an electronic f/stop timer and find it extremely useful. I also own a practical darkroom lightmeter, but it is only used to get the base exposure and contrast within the 'ball park'. Highly sophisticated darkroom meters, which promise quality one-off prints, only add their own set of challenges. On the other hand, one simple test strip provides invaluable information throughout the entire print session and takes relatively little effort. I prefer to determine the optimum print exposure and contrast, while comparing a properly made test strip to others that are just too light, dark, soft or hard. I feel uncomfortable blindly trusting a machine, which dictates a one-and-only setting, without ever getting a chance to evaluate alternatives. We are well advised not to replace skill with technology, otherwise craftsmanship will deteriorate. Producing a truly fine print demands the manual 'exploration' of the whole negative. Especially beginners are better off investing the time to improve their skills, rather than compensating for the lack thereof with overly sophisticated technology. Otherwise, they will develop a dependency that will undoubtably condemn them, and their prints, to an undeserved mediocrity. Fine-art printing is a skill, patiently acquired by training, not just another repetitive process that would benefit from complete automation.

## Expose for the Highlights

The old axiom for preparing high-quality negatives is 'expose for the shadows and develop for the highlights'. It is still valid today. Having learned from the last two chapters, we will modify this rule for preparing high-quality prints to 'expose for the highlights and control the shadows with contrast'.

Our first test strip in fig.1 is made for the highlights only. In this example, the model's top is the most prominent and important highlight in this image, which is why this area of the print was chosen for the test strip. With this test, we will only concentrate on the proper exposure for the highlights. Grade 2, a slightly soft default contrast for diffusion enlargers, was used. The beginning, and sometimes even the experienced, printer has a difficult time to keep from judging the contrast in the first test strip as well. We will resist all temptation to make any evaluation about contrast in the first test strip and wait for a full sheet to do so. For now, all we are interested in is getting the best exposure time for the delicate highlights.

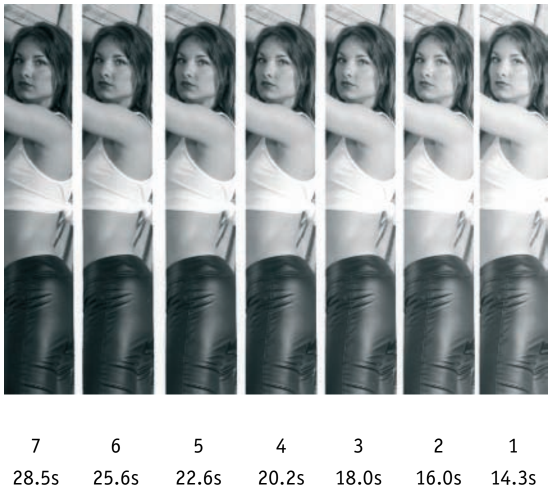


fig.1 The test strip shows the same area of the image with increasing exposure from right to left to determine highlight exposure.

The test strip shows increasing exposure times from the right at 14.3 s to the left at 28.5 s, in 1/6-stop increments at a constant aperture of f/11. This group of students felt that the model's top was slightly too light in step 5 (22.6 s) and slightly too dark in adjacent step 6 (25.4 s). We consulted the f/stop timing chart and settled for an exposure time of 24.0 s, while still ignoring the shadows.

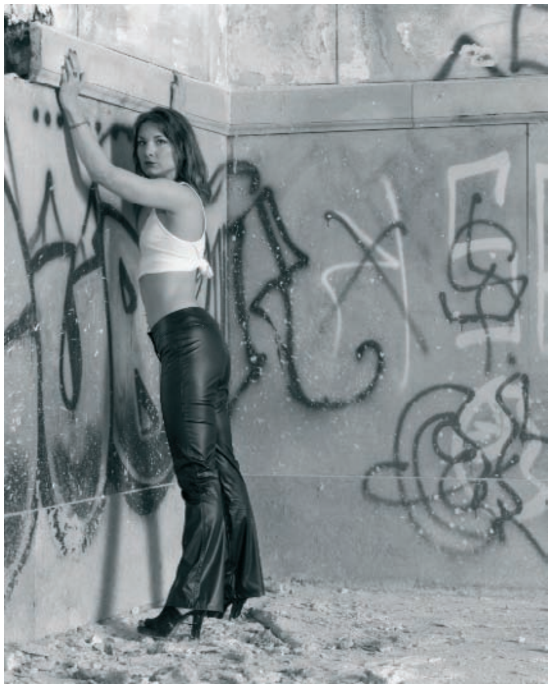
## Control the Shadows with Contrast

Proper global contrast can only be appropriately evaluated on a full sheet exposure. Consequently, we exposed a full sheet, still using grade 2, now that we had the correct highlight exposure.

I prefer to conduct exposure and contrast evaluations under fairly dim incandescent light. A 100-watt bulb about 2 m (6 feet) away will do fine. Fluorescent light is too strong and will most likely result in prints that are too dark under normal lighting conditions.

Our first full sheet in fig.2 was declared to be too dull and too weak in the shadows. It needed a bit more contrast. Another sheet, fig.3, was exposed at grade 2.5,

Use f/stop timing and make a series of test strips to determine the optimum highlight exposure. Then, expose a full-sheet test print to check and adjust the global contrast.
The result is the first work print, having the best exposure and contrast to render significant highlights and shadows as intended. It becomes the basis for all subsequent image manipulations to optimize the print.



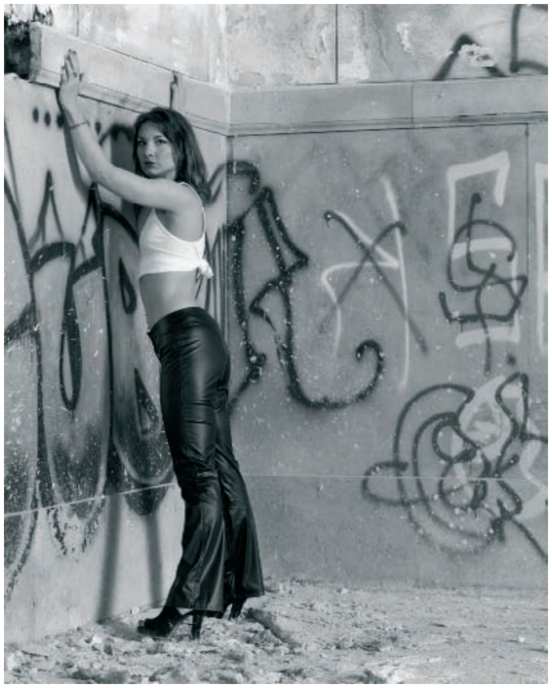


fig.2 (far left) This is the first full-sheet test print with proper exposure to the highlights. The overall contrast of grade 2 is too weak.

fig.3 (left) Here the contrast has been raised to grade 2.5, adding more strength to the shadows, but now, the light wall above the model's head is too distracting.

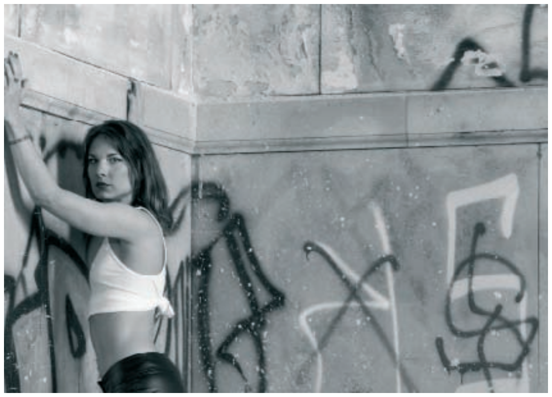
but the exposure was kept constant to maintain highlight exposure. The 1/2-grade increase in contrast made a significant difference and any further increase would have turned some of the shadows, in the dark clothing, into black without texture. The global contrast was now fine, but further work was necessary.

## Direct the Viewer's Eye

The human eye and brain have a tendency to look at the brighter areas of the image first. We can create a far more expressive print if we can control the viewer's eye. This can be accomplished by highlighting the areas of interest and tuning areas with less information value down. Dodging and burning are the basic techniques to do so.

The light wall above the model's head in fig.3 is drawing too much undeserved attention. The viewer is most likely distracted by it and may even look there first. We would like the viewer to start his visual journey with the model, which is the main feature of this image.

In fig.4 and fig.5, an attempt was made to dim the distracting part of the wall down. Fig.4 received the base exposure of 24.0 s at grade 2.5 and an additional



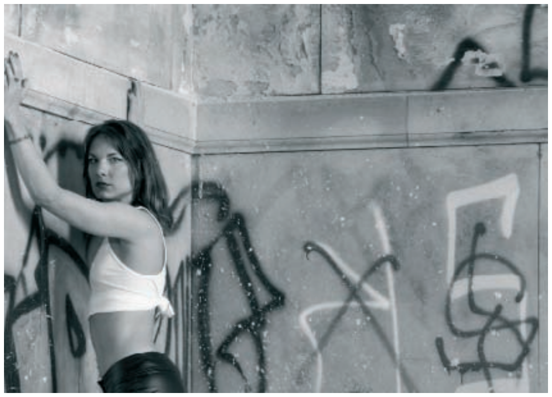
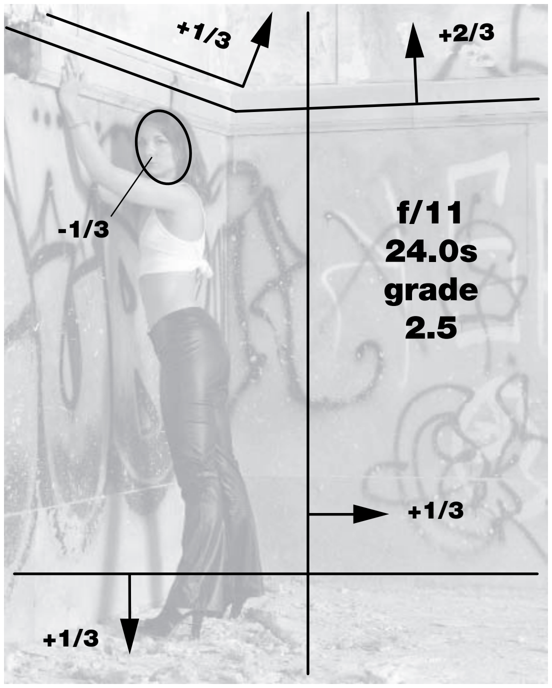


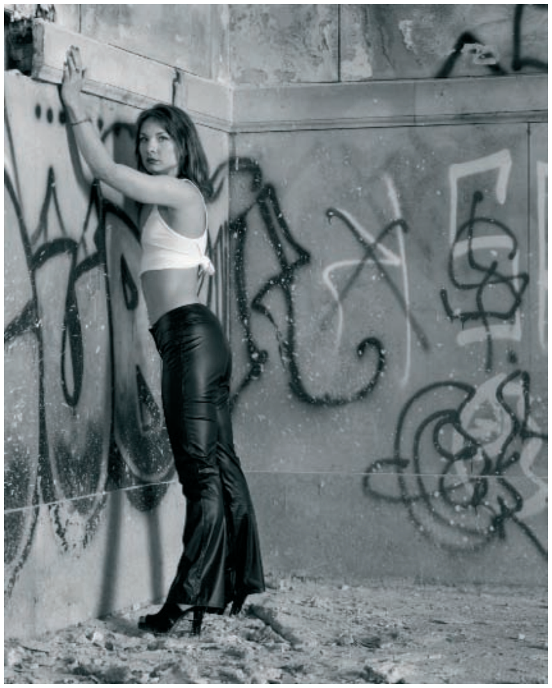
fig.4 (far left) The top wall is burned-in for an additional 1/3 stop.

fig.5 (left) The top wall is burned-in for an additional 2/3 stop.

fig.6 (right) the printing map

fig.7 (far right) the final image prior to toning





exposure of 1/3 stop (6.2 s) to the upper wall by using a burning card. Fig.5 received a similar treatment, but this time the additional exposure to the wall was 2/3 stop (14.1 s). Two things are worth mentioning at this point. I don't perform these burn tests on a full sheet but do it with smaller pieces in the areas of interest, and I usually perform at least two, so I can establish a trend. This shows us that the right side of the wall was about right in tonality, but the left side was still too bright. From the two samples, I estimated that an additional 1/3 stop was required on the left to match the tonality across the top wall.

The face of the model seemed a bit too dark to attract immediate attention. Therefore, I dodged the face with a small dodging tool, for the last 4.9 s (1/3 stop) of the base time, while rapidly moving it, so not to leave any visible marks. To attract further attention to the model, a 1/3-stop edge-burn to the right and lower side was applied. All of the exposures were collected into the printing map shown in fig.6. This is done first on little pieces of scrap paper or on the back of the print. After the darkroom session, it is recorded onto a print card, which is filed with the negative for future use.

The results are shown in fig.7 and in the lead picture. With a few methodical steps a much more communicating image was achieved. The viewer's eyes are not left to aimlessly wander, and the model is not obscurely blending into her surroundings anymore. The model is now clearly the main focus of attention, and the background has been demoted to the important, but secondary, function of supporting and emphasizing the difference between the urban decay and the young woman's beauty.

Preparing additional test strips, to determine the best exposure deviations for dodging and burning, can be laborious, but optimized print manipulation remains pure guesswork without them. As a very effective alternative, prepare additional full-sheet test prints with -1/3, +1/3 and +2/3-stop exposures or as required. These allow for more educated guesses and save time and paper.

# Archival Print Processing

## Challenging the test of time

In an exponentially changing world, one increasingly looks backwards for a sense of stability. It is comforting for photographers to know that their images will survive the ravages of time to become an important legacy for the next generation. Although the need for archival processing is often a personal ambition, rather than a necessity, the qualities required of a print depend on circumstance. For instance, prints destined for collectors of fine art require archival qualities, simply due to the extremely high, but fully justified, customer expectations in this special market.

Additionally, fine-art prints, exhibition work and portfolio images not only require archival processing, but they also demand the extra effort of careful presentation and storage. With reasonable care, the lifetime of a silver image can approach the lifetime of its paper carrier. Fiber-base (FB) prints, combined with a carefully controlled full archival process, have the best chance of permanence. This is confirmed by many true natural-age photographic images from the mid 1800s, which still show no sign of image deterioration. Although resin-coated (RC) prints also benefit

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50007-7

| processing step | | time [min] | print processing | comments |
|---|---|---|---|---|
| 1 | Developer | 3 - 6 | Develop fiber-base paper with constant agitation at supplier-recommended strength, using factorial development times. | The exposed portion of the silver-halide emulsion is reduced to metallic silver during development. It is best to develop fiber-base papers using factorial development. The emerging time of important midtones is recorded and multiplied by a factor. This factor (typically 4-8x) is kept constant to compensate for temperature deviation and developer exhaustion but can be modified to control image contrast. The unexposed portion of the silver-halide emulsion remains and impairs the immediate usefulness of the photograph, until removed in the fixing bath. |
| 2 | Stop Bath | 1 | Agitate lightly in supplier-recommended strength, to terminate print development. | The stop bath is made of either a light acetic or citric acid. It will neutralize the alkaline developer quickly and bring development to a complete stop. Alternatively, a plain water rinse may be used. |
| 3 | 1st Fix | 1 - 2 | Use ammonium thiosulfate (rapid) fixer without hardener at film strength. Agitate prints during fixing, and optionally rinse briefly between baths to prolong the activity of the second bath. Check silver contamination of the first bath frequently with silver estimators, and promote 2nd fix to 1st fix when first bath has reached 0.5-1 g/l silver thiosulfate. Replace both baths after five such promotions. | During fixing, the residual silver halide is dissolved by thiosulfate without damaging the metallic silver image. The first fixing bath does most of the work but becomes increasingly contaminated by the soluble silver thiosulfate and its complexes. Soon, the entire chain of complex chemical reactions cannot be completed successfully, and the capacity limit of the first fixing bath is reached. A fresh second bath ensures that all remaining silver halides and silver thiosulfate complexes are dissolved. An intermediate rinse is optional, but it protects the second bath from contamination. Fixing time must be long enough to render all residual silver halides soluble, but not so long as to allow the fixer and its by-products to permeate the paper fibers; the former being far more important than the latter. Conduct a test to determine the optimum fixing time for any paper/fixer combination. |
| 4 | Rinse | 1 | | |
| 5 | 2nd Fix | 1 - 2 | | |
| 6 | Wash | 10 - 60 | Remove excess fixer prior to toning to avoid staining and highlight loss. The choice of toner and toning process dictates the washing method and time. | Excess fixer causes staining and highlight loss with some toners. This step removes enough fixer to avoid this problem. For selenium toning, a brief 10-minute wash is sufficient. For direct sulfide toning, a 30-minute wash is required. However, the bleaching process required for indirect sulfide toning calls for a complete 60-minute wash prior to toning. Otherwise, residual fixer will dissolve bleached highlights before the toner has a chance to 'redevelop' them. |
| 7 | Toner | 1 - 8 | Choose a time and dilution according to the supplier recommendations or the desired color change and agitate frequently. | Sulfide, selenium or gold toner is essential for archival processing. They convert sensitive image silver to more stable silver compounds. Process time depends on type of toner used, the level of protection required and the final image color desired, but indirect sulfide toning must be done to completion. Some toners can generate new silver halide and, therefore, require subsequent refixing, but this is not the case with sulfide or selenium toner. |
| 8 | Rinse | 5 | Rinse briefly to remove excess toner to avoid staining and to prolong washing aid life. | To quickly remove toner residue, and to avoid highlight staining with sulfide toners, toning must be followed by a brief, but rapid, initial rinse before the print is placed into the wash. Excess toner also contaminates the washing aid and reduces its effectiveness. This increases washing aid capacity. |
| 9 | Washing Aid | 10 | Select a dilution according to supplier recommendation and agitate regularly. | This process step is a necessity for serious archival processing. It significantly supports removal of residual fixer in the final wash. Washing aid also acts as a 'toner stop bath' after direct sulfide toning. This protects the image from 'after-toning' in the final wash. |
| 10 | Wash | 30 - 60 | Use tray or syphon for single prints or vertical print washers for multiple-print convenience. Make sure to provide even water flow over the entire print surface at 20-27°C, and wash until residual thiosulfate levels are at or below 0.015 $g/m^2$. | The fixed photograph still contains considerable amounts of fixer together with small, but not negligible, amounts of soluble silver thiosulfate complexes. The purpose of washing is to reduce these chemicals to miniscule archival levels and thereby significantly improve the stability of the silver image. Print longevity is inversely proportional to the residual fixer in the paper. However, traces of residual fixer may actually be helpful in protecting the image. A simple test will verify washing efficiency. |
| 11 | Stabilizer | 1 | Use the supplier-recommended strength, wipe surplus from the print and dry normally. | Silver stabilizers, applied after washing, will absorb soluble silver formed by oxidant attack. Consequently, they provide additional archival protection but are a poor replacement for toning. |

fig.1 Maximum permanence and archival qualities in FB prints are achieved with these processing recommendations. RC prints will also benefit, but reduce development to 90 s, each fix to 45 s, drop the washing aid and limit washing to 2 min before and 4 min after toning. All processing times include a 15s allowance, which is the typical time required to drip off excess chemicals.

from archival processing, our knowledge of their stability is based on accelerated testing rather than true natural age. This lack of historical data limits serious application to fine-art photography but should not be a concern for commercial photography.

In short, archival processing requires the developed image to be (1) well-fixed to remove all unexposed silver, (2) toned appropriately to protect the remaining image silver and (3) washed thoroughly to remove potentially harmful chemicals from the emulsion and the paper fibers. Archival storage requires the final photograph to be mounted and kept in materials that are free of acids and oxidants, meeting the requirements of ISO 18902. They must also be protected from direct sunlight, temperature and humidity extremes, as well as other potentially harmful environmental conditions and pollution.

## Fixing

The light-sensitive ingredient of photographic paper is insoluble silver halide. During development, previously exposed silver halides are reduced to metallic silver in direct proportion to the print exposure, but the unexposed silver halides remain light sensitive and, therefore, impair the immediate usefulness of the photograph and its permanence. Consequently, all remaining silver halides must be made soluble and removed through fixing.

Commercial fixers are based on sodium or ammonium thiosulfate and are often called 'hypo', which is short for hyposulfite of soda, an early but incorrect name for sodium thiosulfate. Ammonium thiosulfate is a faster acting fixer and is, therefore, referred to as 'rapid fixer'. Unfortunately, some practitioners have continued using the erroneous term and expanded it referring to any type of fixer as 'hypo' now.

Fixers can be plain (neutral), acidic or alkali. Plain fixers have a short tray life and are often discounted for that reason. Most common are acidic fixers, as they can neutralize any alkali carry-over from the developer and, in effect, arrest development. Alkali fixers are uncommon in commercial applications but find favor with specialist applications, such as maximizing the stain in pyro film development and retaining delicate highlights in lith-printing. At equivalent thiosulfate concentrations, alkali fixers work marginally quicker than their acid counterparts and are more easily removed during the final print washing.

## Fixing Process

For optimum silver-halide removal and maximum fixer capacity, prints are continuously agitated in a first fixing bath for at least 2x the 'clearing' time (typically 1-2 minutes), followed by an optional brief rinse and a second fixing bath for the same amount of time. The 'clearing' time is the least amount of fixing time required to dissolve all silver halides and is determined through a separate test. The initial fixing-bath duo is used until the silver contamination of the first bath reaches the limit for archival processing, at which point the bath is exhausted and, therefore, discarded. The second bath is then promoted to take the place of the first, and fresh fixer is prepared to replace the second fixing bath. After five such changes, both baths are replaced by fresh fixer. The optional intermediate rinse reduces unnecessary carry-over of silver-laden fixer into the second fixing bath.

During the fixing process, the residual silver halides are dissolved by thiosulfate without any damage to the metallic silver forming the image. The resulting soluble silver thiosulfate and its complexes increasingly contaminate the fixing bath until it no longer dissolves all silver halides. Eventually, the solution is saturated to a point at which the capacity limit of the fixer is reached. The fresher, second bath ensures that any remaining silver halides and all insoluble silver thiosulfate complexes are rendered soluble.

## Fixer Strength

Kodak recommends paper fixer strength to be about half as concentrated as film fixer. For archival processing, Ilford recommends the same 'film-strength' fixer concentration for film and paper. Kodak's method exposes the paper to relatively low thiosulfate levels for a relatively long time, where Ilford's method exposes the paper to relatively high thiosulfate levels for a relatively short time. It has been suggested that this reduces fixing times to a minimum and leaves little time for the fixer to contaminate the paper fibers. Conversely, whatever fixer does get into the fibers is highly concentrated and takes longer to wash out.

The best fixing method is clearly the one that removes all residual silver, while leaving the least possible amount of fixer residue in the paper fibers during the process. Whichever of the above methods is more advantageous depends greatly on the composition of the silver-halide emulsion and the physical properties of the fiber structure onto which it is coated. Start with the manufacturer's recommendation, but ultimately, it is best to test your chosen materials for optimum fixing and washing times at low and high fixer concentrations.

The process instructions, shown in fig.1, assume the use of rapid fixer at film-strength (10% ammonium thiosulfate concentration). A primary concern with strong fixing solutions and long fixing times is the loss of image tones due to oxidation and solubilization of image silver. Fig.2 shows how several reflection densities are affected by film-strength fixer over time. Fixing times of 2-4 minutes do not result in any visible loss of density, but excessive fixing times will reduce image densities considerably. The density reduction is most significant in the silver-rich image shadows; however, the eye is more sensitive to the midtone and highlight density loss. Data is not available for density loss using paper-strength dilution, but it is conceivable for it to be significantly less.

## Fixing Time

By the time it reaches the fixer, each 16x20-inch sheet of FB paper carries 25-35 ml of developer and stop bath. The fixing time must be long enough to overcome dilution by these now unwanted chemicals,

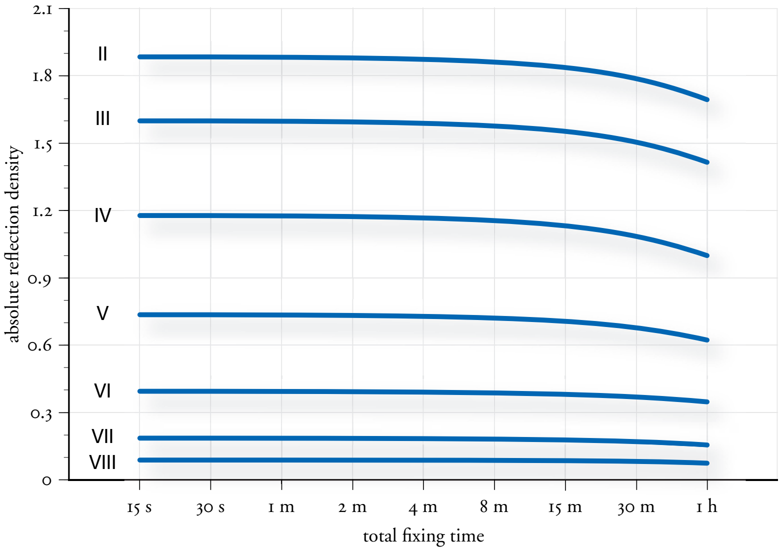


fig.2 Fixing times of 2-4 minutes do not result in any visible loss of density, but excessive fixing times will reduce image densities considerably.

penetrate the emulsion layer and convert all remaining silver halides. However, if the fixing time is too long, the thiosulfate and its by-products increasingly contaminate the print fibers and become significantly harder to wash out. Consequently, archival processing has an optimum fixing time.

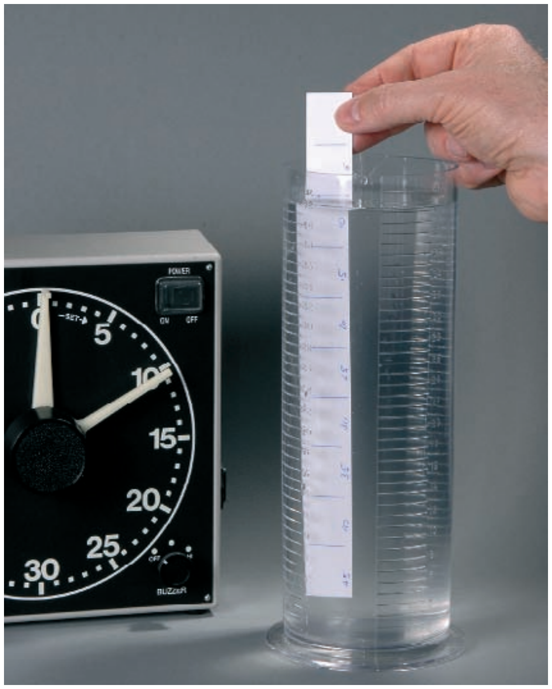


fig.3a Determine the optimum fixing time with a 1x10-inch test strip, marked in 5s increments. Immerse the strip into a fresh fixing bath, starting with the 45s patch, and continue to immerse an additional patch every 5 seconds, while agitating constantly.

**Testing for the Optimum Fixing Time**

The recommended fixing times, shown in fig.1, have been tested and work well for current Ilford (1 min) and Kodak papers (2 min), but the optimum fixing time depends on the type of emulsion, the type of fixer and the concentration of the fixer. We suggest you use the following test to establish the optimum fixing times for each paper/fixer combination.

1. Cut a 1x10-inch test strip from the paper to be tested. Turn on the room lights, fully exposing the test strip for a minute. Avoid excessive exposure or daylight, as this will leave a permanent stain.
2. Dim the lights, and divide the test strip on the back into patches, drawing a line every inch (fig.3b). Mark the patches with fixing times from '45 s' down to '5 s' in 5s increments. Leave the last patch blank to use as a 'handle'.
3. Place the whole strip into water for 3 minutes and then into a stop bath for 1 minute to simulate actual print processing conditions.
4. Immerse the strip into a fresh fixing bath, starting with the 45s patch, and continue to immerse an additional patch every 5 seconds, while agitating constantly (fig.3a).
5. Turn the lights on again, and thoroughly wash the test strip for 1 hour under running water to remove all traces of fixer, and tone in working-strength sulfide toner for 4 minutes. Then, wash again for 10 minutes and evaluate.

If the entire test strip is paper-white, all fixing times were too long. If all patches develop some density in form of a yellow or brown tone, all fixing times were too short. Adjust the fixing times if necessary and retest. A useful test strip has two or three indistinguishable paper-white patches towards the longer fixing times (fig.3b). The first of these patches indicates the minimum 'clearing' time. Double this time to include a safety factor, allowing for variations in agitation, fixer strength and temperature, and the result is the optimum fixing time. Be careful, however, not to use a fixing time of less than 1 minute, as it is difficult to ensure proper print agitation in less time, and patches of incomplete fixing might be the result. Use the optimum fixing time, but at least 1 minute for each bath, allowing the first bath to be used until archival exhaustion. After all, incomplete fixing is the most common cause for image deterioration.

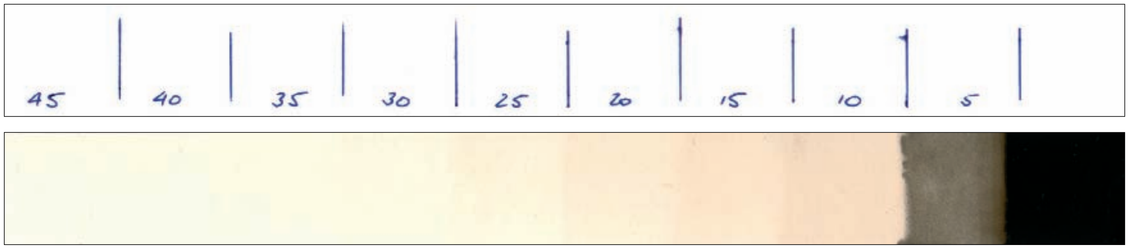
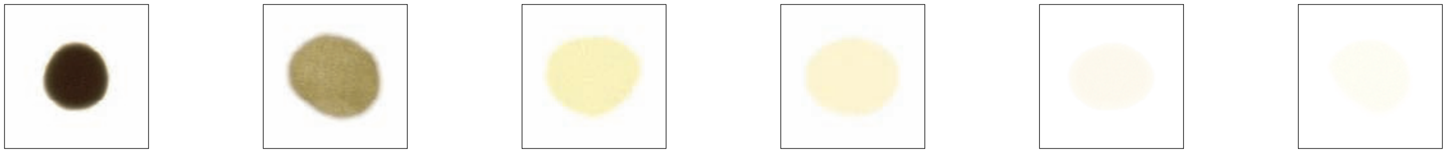


fig.3b A useful test strip has two or three indistinguishable paper-white patches towards the longer fixing times after processing. The first of these patches indicates the 'clearing' time (approximately 30-35 seconds in this example). Double this time to determine the optimum fixing time.



a) no fixer b) weak fixer (30s) c) weak fixer (60s) d) old fixer (120s) e) old/fresh (60/60s) f) fresh/fresh (60/60s)

fig.4 Incomplete fixing is detectable by sulfide toning. Process a test strip and apply a drop of working-strength sulfide toner to it for 4 minutes. The toner reacts with silver halides left behind by poor fixing and creates brown silver sulfide. Any stain in excess of a barely visible pale cream indicates incomplete fixing.

a) Working-strength sulfide toner applied to an unprocessed piece of Ilford Multigrade IV FB paper.

b-c) Fixed for 30 and 60 seconds in highly diluted (1+19) rapid fixer.

d) Fixed for 2 minutes in exhausted film-strength (1+4) rapid fixer.

e-f) Two-bath fixed for 1+1 minutes in exhausted+fresh and fresh+fresh film-strength rapid fixer.

Optimum print fixing reduces non-image silver to archival levels of less than 0.008 g/m$^2$, but periodically, a process check is in order. As we have seen, incomplete fixing, caused by either exhausted or old fixer, insufficient fixing time or poor agitation, is detectable by sulfide toning. Apply a drop of working-strength sulfide toner to an unexposed, undeveloped, fixed, fully washed and still damp, test strip for 4 minutes (fig.4). The toner reacts with silver halides left behind by poor fixing and creates brown silver sulfide. Any stain in excess of a barely visible pale cream indicates the presence of unwanted silver and, consequently, incomplete fixing. Compare the test stain with a well-fixed material reference sample for a more objective judgment.

### Fixer Capacity

The maximum capacity of the first fixing bath can be determined either by noting how many prints have been processed or, more reliably, by measuring the silver content of the fixer solution with a test solution or a silver estimator. Tetenal's estimator (fig.5) provides small test papers, similar to pH test strips, to estimate silver thiosulfate levels from 0.5-10 g/l. A test strip is dipped briefly into the fixer solution, and its color is compared against a calibrated chart after 30 seconds. For archival processing, discard the first fixing bath as soon as the silver thiosulfate content has reached 0.5-1.0 g/l. This occurs with images of average print density after each liter of chemistry has processed about twenty 8x10-inch prints. At the same time, the silver thiosulfate content of the second fixing bath is only about 0.05 g/l. For less stringent commercial photography, many printers process up to fifty 8x10-inch prints per liter, allowing the first bath to reach 2.0 g/l silver thiosulfate and the second bath to contain up to 0.3 g/l. These levels are too high for true archival processing.

### Hardener

Some fixers are available with print hardener optional or already added. Hardeners were originally added to fixers to aid in releasing the emulsion from ferrotyping drying drums. This type of drier is not popular anymore, because its cloth-backing is difficult to keep clean of chemical residue, which may contaminate the print. The hardener also protects the print emulsion from mechanical handling damage during the wet processes. Unfortunately, toning and archival washing are impaired by print hardener, leading to longer processing times. In our opinion, the disadvantages are not worth the questionable benefit, and consequently, we do not recommend the use of print hardener, unless when using a mechanized print processor whose rollers may cause scratches.

## Toning

Toning converts the image forming metallic silver to more inert silver compounds, guarding the image against premature deterioration due to environmental attack. The level of archival protection is proportional to the level of image silver conversion, and anything short of a full conversion leaves some vulnerable silver behind. ISO 18915, the test method for measuring the resistance of toned images to oxidants, recommends at least a 67% conversion. Nevertheless, toning causes an unavoidable change in image tone and density (see fig.7). In many cases, a pronounced tonal change is desired, because it appropriately supports the aesthetic

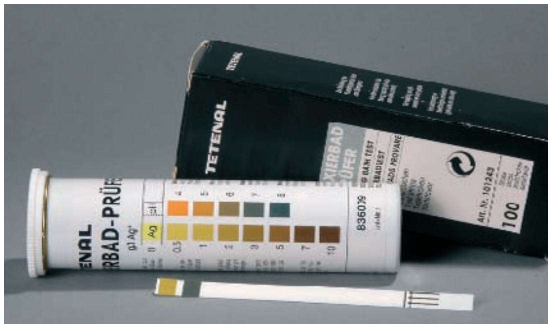


fig.5 Tetenal's estimator provides small test papers, similar to pH test strips, to estimate silver thiosulfate levels from 0.5-10 g/l. A strip is dipped into fixer, and its color is compared against a calibrated chart.

AGFA
VIRADON NEW
BROWN TONER
Cont.: 125 ml
Kodak Professional
rapid selenium toner
for films and papers
Net Contents
1 U.S. Quart
946 mL
CAT 146 4486

fig.6 Sulfide toners effectively convert metallic image silver to the far more stable silver sulfide. Agfa Viradon is a polysulfide toner, mainly used for direct toning. Even short direct toning provides strong image protection with minimal change in image color. Selenium toners convert metallic image silver to the more inert silver selenide and giving a range of tonal effects. Light toning in Kodak Rapid Selenium Toner mildly protects the print, starting with the shadows, without an obvious color or density change. Combination toning with selenium and sulfide is recommended to protect all print tones.

effects intended. However, an obvious change in image tone and density is not always suitable or wanted. To avoid any tonal and density changes, some printers consider toning an option and rely on post-wash treatments, such as Agfa's Sistan silver stabilizer, alone. The image silver will likely benefit from the stabilizer, but some toning is certainly better than none. An informed printer makes an educated choice, balancing the aesthetics of tonal and density changes with the benefits of image protection.

There are three commonly agreed archival toners: sulfide, selenium and gold. Platinum may also deserve to be added to this list, but its high cost is hard to justify, since it does not provide increased image protection in return. Additional toners are available, including iron (blue toner), copper (red toner) and dye toners. However, they are known to actually reduce the life expectancy of an image, compared to a standard B&W print, and consequently, these non-archival toners should only be considered for aesthetic toning purposes.

The exact mechanisms of silver image protection are not completely understood and are still controversial, but the ability of archival toners to positively influence silver image permanence is certain. Nevertheless, many toners contain or produce highly toxic chemicals and some are considered to be carcinogenic. Please follow the safety instructions included with each product.

### Sulfide Toning

For aesthetic or archival reasons, sulfide toners have been in use since the early days of photography. They effectively convert metallic image silver to the far more stable silver sulfide. Sulfide toning is used either as direct one-step (brown) toning or as indirect two-step, bleach and redevelop, (sepia) toning. Even short direct sulfide toning provides strong image protection with minimal change in image color. Indirect sulfide toning, on the other hand, yields images of greater permanence, although a characteristic color change is unavoidable. Indirect toning requires print bleaching prior to the actual toning bath. The bleach leaves a faint silver bromide image, which the toner then redevelops to a distinct sepia tone. Several sulfide toners are available for the two different processes:

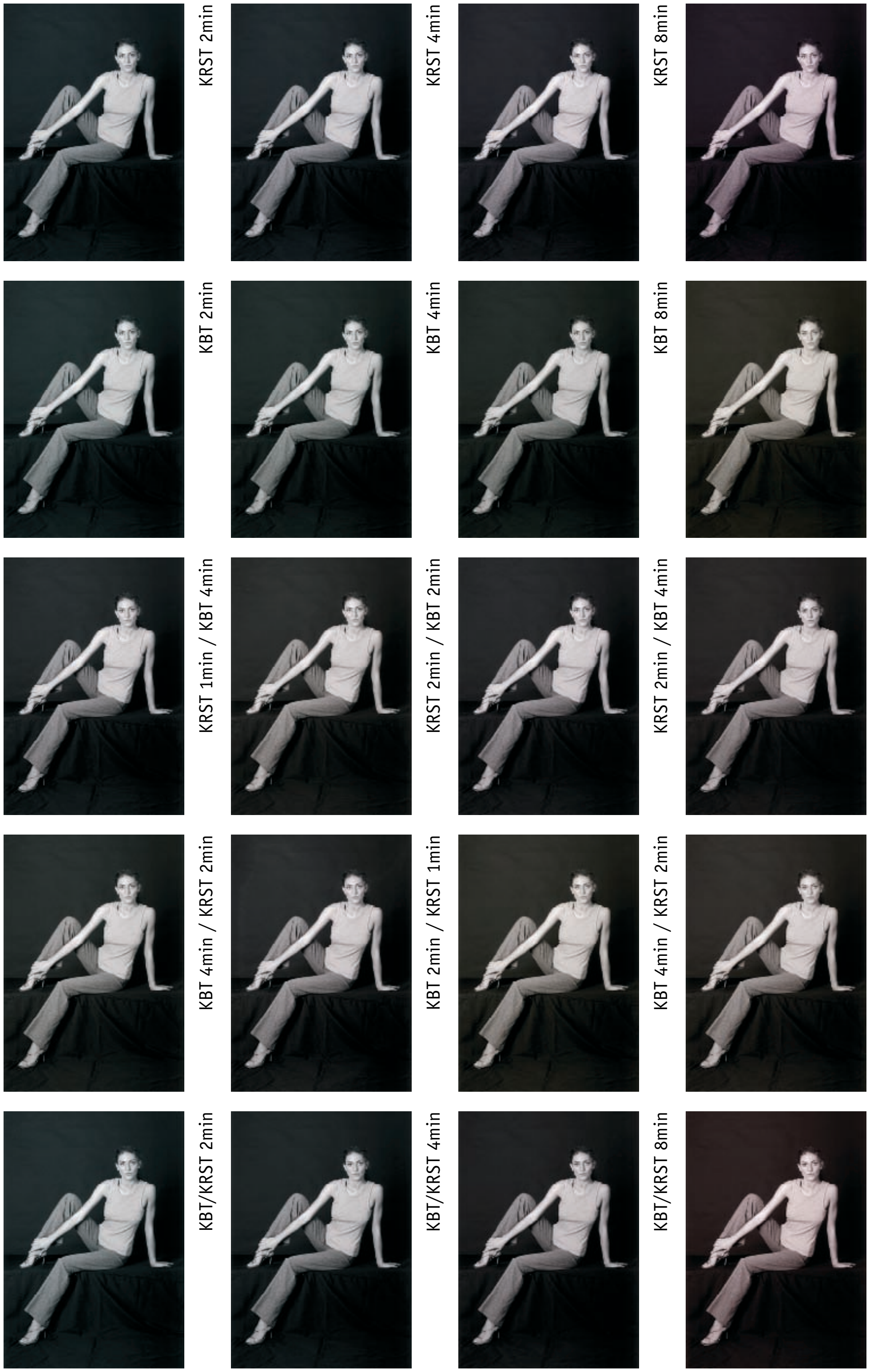
### Indirect Sulfide Toner

1. Sodium sulfide toners, such as Kodak Sepia Toner, are indirect toners. Similar products are available from Photographers' Formulary and Tetenal. They produce hydrogen sulfide gas (the rotten egg smell), which is a toxin at higher concentrations. It can fog photographic materials and is highly unpleasant, if used without sufficient ventilation. Nevertheless, sulfide was the toner of choice for most of the old masters. The indirect method had the added benefit of lowering the contrast and extending the contrast range. This salvaged many prints, which were not very good before toning, and 100 years ago, variable contrast papers were not available.
2. Odorless toners use an alkaline solution of thiourea (thiocarbamide) to convert the image silver to silver sulfide. They are effective indirect toners and are more darkroom-friendly than their smelly counterparts, but they are still a powerful fogging agent. Odorless toners are available from Fotospeed, Photographers' Formulary and Tetenal. Some of these products allow the resulting image color to be adjusted through pH control.

### Direct Sulfide Toner

3. Polysulfide toners, such as Kodak Brown Toner (potassium polysulfide), Agfa Viradon (sodium polysulfide) and Photographers' Formulary Polysulfide, can be used for both, direct and indirect toning. These toners also produce toxic hydrogen sulfide gas, as well as the offensive odor that goes

untoned print



KRST 1min
KRST 2min
KRST 4min
KRST 8min

KBT 1min
KBT 2min
KBT 4min
KBT 8min

KRST 1min / KBT 2min
KRST 1min / KBT 4min
KRST 2min / KBT 2min
KRST 2min / KBT 4min

KBT 2min / KRST 1min
KBT 4min / KRST 2min
KBT 2min / KRST 1min
KBT 4min / KRST 2min

KBT/KRST 1min
KBT/KRST 2min
KBT/KRST 4min
KBT/KRST 8min

fig.7 Toning protects the image against premature deterioration, but causes an unavoidable change in image tone and density. In many cases, a pronounced tonal change is desired, because it appropriately supports the aesthetic effects intended. However, an obvious change in image tone and density is not always suitable or wanted. The examples, shown here, illustrate the tonal changes in Agfa Multicontrast Premium RC paper, due to various combinations and levels of archival toning in Kodak Rapid Selenium Toner (KRST 1+19) and/or Kodak Brown Toner (KBT 1+31). An informed printer makes an educated choice, balancing the aesthetics of tonal and density changes with the benefits of image protection.

along with it. But when direct toning is preferred, they are highly recommended for use on their own or in combination with a selenium toner, as long as adequate ventilation is available.

4. Hypo-alum toners are odorless direct toners. They require the addition of silver nitrate as a 'ripener'. Consequently, they are not as convenient to prepare as other sulfide toners, and toning can take from 12 minutes in a heated bath up to 12 hours at room temperature. These 'vintage' toners give a reddish-brown tone with most papers and are still available from Photographers' Formulary.

Residual silver halide, left behind by poor fixing, will cause staining with sulfide toners. Furthermore, residual thiosulfate, left behind by poor washing, can also cause staining and even highlight loss with sulfide toners. To avoid staining from residual silver halide or thiosulfate, it is, therefore, essential that FB prints are fully fixed and adequately washed in preparation for, or anticipation of, sulfide toning.

For direct sulfide toning, a preceding 30-minute wash is sufficient. This wash is also required for direct sulfide toning subsequent to selenium toning, as selenium toner contains significant amounts of thiosulfate itself. The bleaching process, required for indirect sulfide toning, calls for a complete 60-minute wash prior to bleaching. Otherwise, residual fixer will dissolve bleached highlights before the toner has a chance to 'redevelop' them. Likewise, a brief rinse after bleaching is highly recommended, because the interaction between bleach and toner may also cause staining. Washing minimizes the risk of unwanted chemical interactions between fixer, bleach, and toner.

Indirect toning, after bleaching, must be carried out to completion to ensure full conversion of silver halides into image forming silver. If warmer image tones are desired, it is often tempting to pull the print from the toning bath early, but it is far better to control image tones with adjustable thiourea toners, and tone to completion. Otherwise, some residual silver halide will be left behind, since the toner was not able to 'redevelop' the bleached image entirely. This is rare, because indirect toning is completed within a few minutes, but if residual silver halide is left behind by incomplete toning, the print will eventually show staining and degenerate, similarly to an incompletely fixed print.

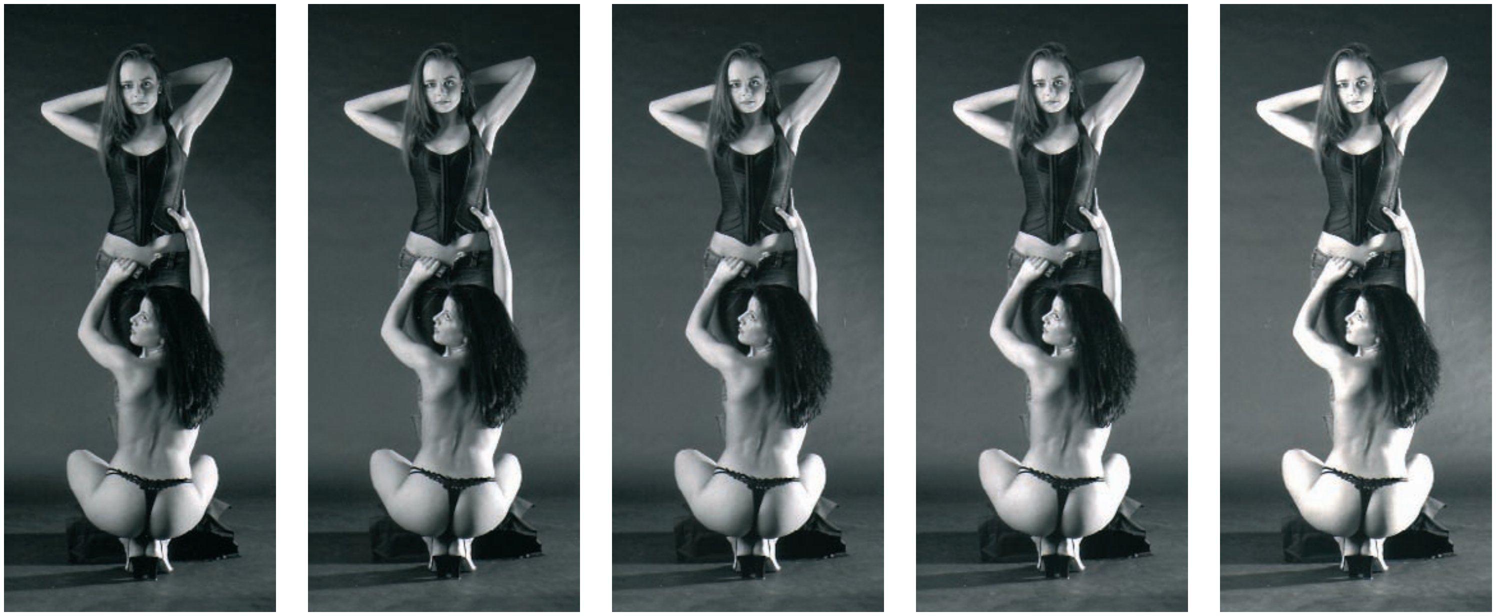
Some polysulfide toners have the peculiar property of toning faster when highly diluted, and an extremely diluted toner can leave a yellow or peach colored stain in the highlights and the paper base. To remove toner residue quickly and to avoid highlight staining, direct polysulfide toning must be followed by a brief, but intense, initial rinse before the print is placed into the wash. Nonetheless, toning will continue in the wash until the toner is completely washed out. To prevent after-toning and possibly over-toning, or staining of FB prints, a 5-minute treatment in 10% sodium sulfite, prior to washing, must be used as a 'toner stop bath'. A treatment in washing aid, before the final wash, also acts as a mild toner stop bath, because sodium sulfite is the active ingredient in washing aid. For the same reason, never treat prints in washing aid prior to sulfide toning, as it would impede the toning process.

Sulfide toner exhaustion goes along with an increasing image resistance to tonal change, even when toning times are significantly extended. At that point, sulfide toner also loses some of its unpleasant odor, develops a heavy yellow precipitate in the bottle and becomes distinctly lighter in color.

### Selenium Toning

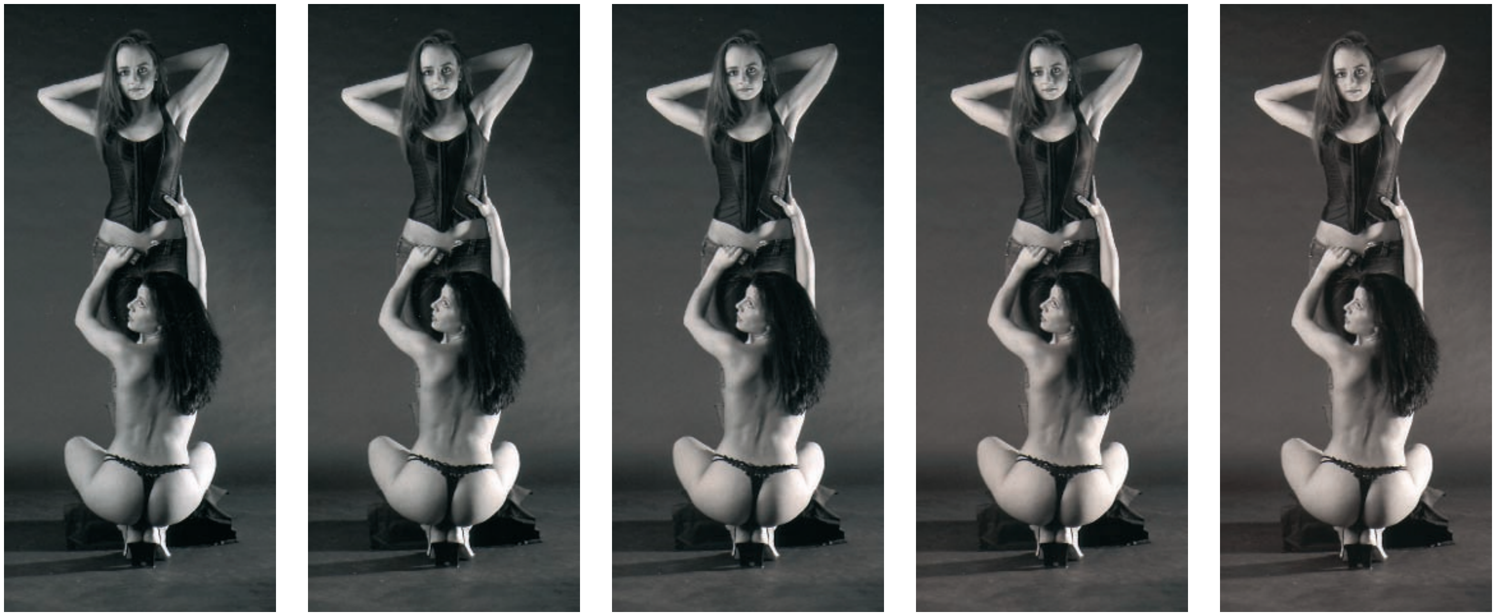
This is a popular fast acting toner, used by most of today's masters, which converts metallic image silver to the more inert silver selenide and gives a range of tonal effects with different papers, developers, dilutions, temperatures and toning times. Selenium toner has a noticeable effect on the silver-rich areas of the print, increasing their reflection density and, consequently, gently darkening shadows and midtones. This slightly increases the paper's maximum black (Dmax) as well as the overall print and shadow contrast. For this reason alone, some practitioners make selenium toning part of their standard routine, in an attempt to conserve some of the wet 'sparkle', which a wet print undoubtedly has, when coming right out of the wash, but otherwise unavoidably loses while drying. Selenium toners are available as a liquid concentrate from Kodak, Fotospeed and a few others. Due to its high toxicity, we recommend against preparing selenium toner from powders.

Depending on the paper, prolonged use of Kodak Rapid Selenium toner, diluted 1+4 or 1+9, makes a very pronounced effect on paper Dmax and image color. Alternatively, a dilution of 1+19 can be used



untoned prints

unbleached bleached for 1 min bleached for 2 min bleached for 4 min bleached for 8 min



toned prints

unbleached bleached for 1 min bleached for 2 min bleached for 4 min bleached for 8 min

fig.8 The level of archival protection through toning is proportional to the level of image silver conversion, and anything short of a full conversion leaves some vulnerable silver behind. It is possible to test the amount of toning by bleaching out the vulnerable image silver. All images, shown here, are on Agfa Multicontrast Premium RC paper, but the bottom row was toned in Kodak Rapid Selenium Toner (1+19) for 1 minute (protecting the shadows), followed by Kodak Brown Toner (1+31) for 2 minutes (protecting the highlights). The prints were subsequently bleached in a 0.1% solution of potassium ferricyanide for 0-8 minutes and refixed. In the untoned prints, bleaching reduced shadow and highlight density for similar amounts, eventually destroying all highlight detail. In the toned prints, bleaching changed image color and reduced shadow density slightly, but the highlights withstood the bleach well. Toned prints resist bleaching better than the untoned prints.

for 1-4 minutes, at which paper Dmax is still visibly enhanced, but the image exhibits less color change. Light selenium toning mildly protects the print without an obvious color or density change. As toning continues, and starting with the shadows, the level of protection increases and the print tones become darker and warmer in color. To increase image protection, selenium toning can be followed by sulfide toning.

As with sulfide toners, residual silver halide, left behind by poor fixing, will also cause staining with selenium toners, and prints must be fully fixed before toning. FB prints also benefit from a 10-minute wash, prior to toning, to prevent potential image staining and toner contamination from acid fixer carryover. Prints processed with neutral or alkali fixers do not require a rinse prior to selenium toning.

Selenium toner exhaustion is heralded by heavy gray precipitates in the bottle, the absence of the noxious ammonia smell and the lack of an image change, even when toning times are significantly prolonged.

### Gold Toning

Gold toner is a slow, expensive and low capacity toner, which is easily contaminated by selenium or polysulfide toners. The resulting image is stable and, in contrast to sulfide toner, 'cools' the image with prolonged application towards blue-black tones. Process recommendations vary from 10 minutes upwards. Gold toning, in combination with selenium or polysulfide toning, can produce delicate blue shadows and pink or orange-red highlight tones.

Some gold toners generate silver halide and, therefore, require subsequent refixing to ensure image permanence. Nelson's Gold Toner specifically requires such refixing. If refixing is skipped, the print will eventually show staining and degenerate, similar to an incompletely fixed print. The subtlety and limited working capacity of gold toner inhibits its exhaustion detection, and therefore, it is often reserved for prints requiring a specific image tone, rather than being used for general archival toning.

### Combination Toning

Strong image protection is achieved through a combination of selenium and polysulfide toning, which converts the image silver to a blend of silver selenide and silver sulfide, protecting all print tones. Combination toning can be carried out by mixing polysulfide and selenium toner, creating a combination toner, or by simply toning sequentially in each toner.

When preparing a selenium-polysulfide toner, final image tones can be influenced by the mixing ratio. Kodak recommends a working-strength selenium-to-polysulfide ratio of 1:4 for warm image tones. Adding 1-3% balanced alkali will stabilize the solution; otherwise, consider the mixture for one-time use only. As with plain, direct polysulfide toning, prints must be fully fixed and washed for 30 minutes prior to combination toning, which is in turn followed by an intense rinse and a washing aid application, before the print is placed into the final wash.

When using selenium and polysulfide toners sequentially, final image tones depend on toning times, as well as the toner sequence. A very appealing split-tone effect can be achieved when selenium toning is applied first. The selenium toner will not only darken the denser midtones and shadows slightly, but it will also shift these image tones toward a cool blue and protect them from much further toning. This will leave the lighter image tones, for the most part, unprotected. The subsequent polysulfide toner then predominantly tones these, still unprotected, highlights and lighter midtones, shifting them toward the typical warm, brown sepia color. This, in turn, has little consequence for the already selenium-toned, darker, blue image tones. The result is an image with cool blue shadows and warm brown highlights. This split-tone effect is most visible at the highlight to shadow borders and can be controlled with different times in each toner. As a starting point, try a selenium-to-polysulfide ratio of 1:2 at 2 and 4 minutes, respectively. For this toning sequence, prints must be fully fixed and washed for 10 minutes prior to selenium toning, and they must be washed again for 30 minutes prior to polysulfide toning, which is then followed by an intense rinse and washing aid, prior to the final wash.

When the split-tone effect is undesired or does not support the aesthetic intent of the image, the toning sequence may be reversed, and polysulfide toning is done first. Fig.7 illustrates some of the appearance differences achievable with plain or combination toning. When selenium toning is done last, prints must be fully fixed and washed for 30 minutes prior to polysulfide toning, which is followed by an intense rinse, washing aid, selenium toning, wash aid again and, ultimately, the final wash.

## Washing

A fixed, but unwashed, print contains a considerable amount of thiosulfate, which must be removed to not adversely affect later processing operations and to optimize the longevity of the silver image. Even if the print was already washed prior to toning, the remaining thiosulfate levels are still far too high for archival image stability, and some toners, for example selenium toner, contain thiosulfate themselves. The principal purpose of archival washing is to reduce residual thiosulfate to a concentration of 0.015 g/m$^2$ (0.01 mg/in$^2$) or less, including the usually small, but not negligible, amount of soluble silver thiosulfate complexes, which otherwise remain in the paper.

The process of print washing is a combination of displacement and diffusion. Just prior to the wash, a relatively large amount of excess fixer is gently clinging to the print through surface adhesion. An initial, brief but rapid, rinse in water quickly displaces this excess fixer, simply washing it off the surface. However, there is still plenty of thiosulfate left in the print, and this is a bit harder to get rid of. It has been deeply absorbed by the emulsion and saturates the print fibers. The remaining thiosulfate can only be removed by the process of diffusion (fig.9).

As long as there is a difference in thiosulfate concentration between the print and the wash water, thiosulfate will diffuse from the print into the water. This gradually reduces the thiosulfate concentration in the print and increases it in the wash water. Diffusion continues until both are of the same concentration and equilibrium is reached, at which point no further diffusion takes place. Replacing the saturated wash water entirely with fresh water repeats the process, and a new equilibrium at a lower residual thiosulfate level is obtained. However, diffusion is an exponential process that decreases geometrically with time. This means that the rate of diffusion slows down rapidly towards the equilibrium. Print washing is quicker if the wash water is not entirely replaced in certain intervals, but slowly displaced with a constant flow of fresh water across the print surfaces, keeping the concentration difference, and therefore the rate of diffusion, at a maximum during the entire wash. Other essential elements for effective washing are the use of washing aid, water replenishment and temperature.

Thiosulfate diffuses from the print emulsion, during washing, with relatively little resistance. Paper fibers and the baryta layer, on the other hand, have a tendency to adsorb residual thiosulfate, which can render washing into a rather sluggish process. This is firstly a reason to keep fixing times as short as possible, and secondly, it is a reason to use washing aids. Washing aids, also known as hypo-clearing agents, are marketed by Ilford, Kodak, Tetenal and others. These products help to desorb thiosulfate and improve washing efficiency. Washing aids are not to be confused with hypo eliminators, which are no longer recommended, because ironically, small residual amounts of thiosulfate actually provide some level of image protection. In addition, hypo eliminators contain

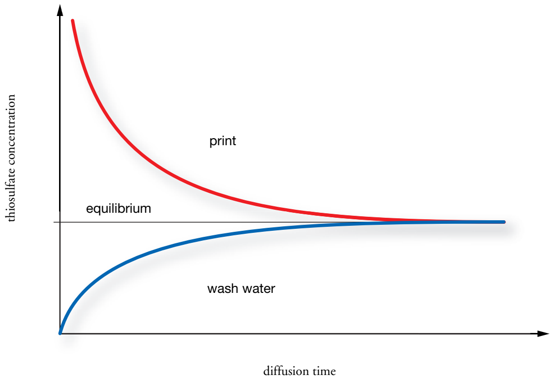


fig.9 As long as there is a difference in thiosulfate concentration between the print and the wash water, thiosulfate will diffuse from the print into the water. This gradually reduces the thiosulfate concentration in the print and increases it in the wash water. Diffusion continues until both are of the same concentration and equilibrium is reached, at which point no further diffusion takes place.

**Residual Thiosulfate Limits for Archival Processing of Photographic Papers**

(in various units)

0.015 g/m$^2$
15.0 mg/m$^2$
0.15 mg/dm$^2$
0.0015 mg/cm$^2$
1.5 µg/cm$^2$

0.01 mg/in$^2$
10.0 µg/in$^2$

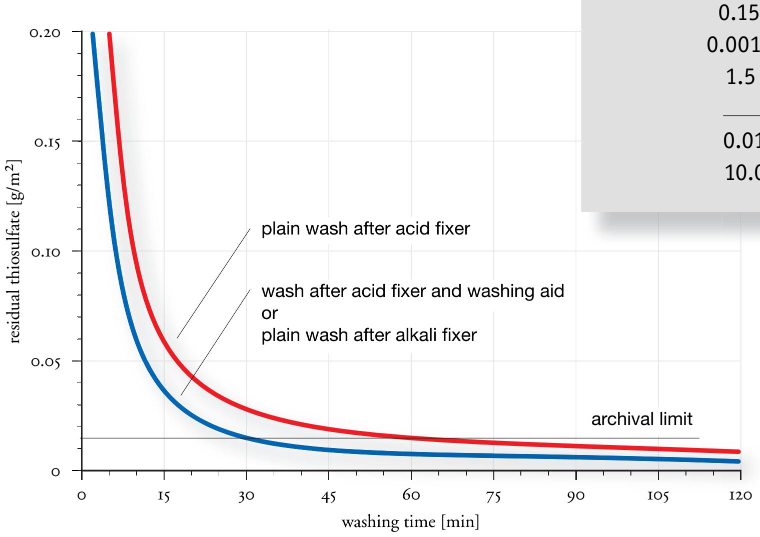


fig.10 The use of washing aid is highly recommended when using acid fixers. It conserves water, reduces the total processing time by about 50% and lowers residual thiosulfate levels below those of a plain wash.

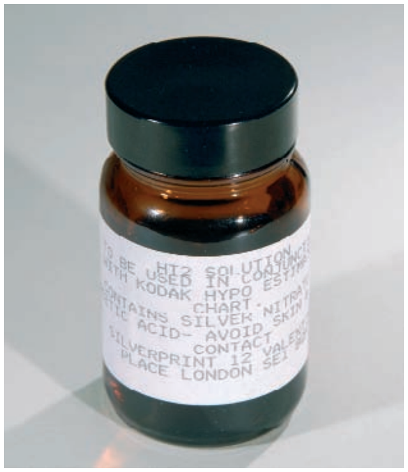
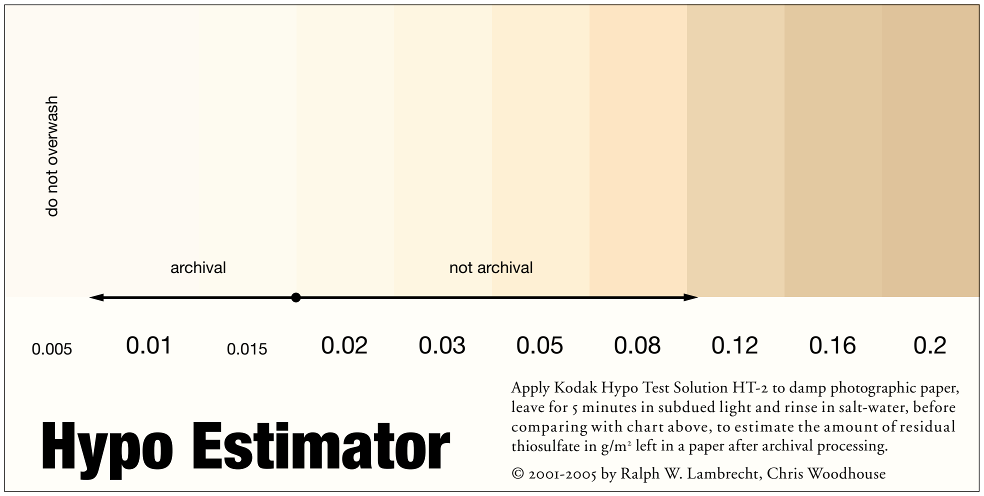


fig.11 Residual thiosulfate, left by the washing process, can be detected with Kodak's light sensitive silver nitrate solution HT2.

fig.12 Residual hypo can be detected with Kodak's hypo test solution, which is applied to the print border for 5 minutes. The color stain left by the solution is an indicator of the hypo level in the paper. Compare the color stain with this chart to estimate residual thiosulfate levels.



Hypo Estimator

Apply Kodak Hypo Test Solution HT-2 to damp photographic paper, leave for 5 minutes in subdued light and rinse in salt-water, before comparing with chart above, to estimate the amount of residual thiosulfate in g/m² left in a paper after archival processing.

© 2001-2005 by Ralph W. Lambrecht, Chris Woodhouse

oxidizing agents that may attack the image. There is little danger of over-washing FB prints without the use of hypo eliminators. However, over-washing is a risk with some RC papers, and the use of washing aid is, therefore, discouraged for RC processing. Nevertheless, with FB prints, the use of a washing aid is highly recommended, because it conserves water, reduces the total processing time by about 50%, and it lowers residual thiosulfate levels below those of a plain wash (see fig.10). Its use increases washing efficiency in cold wash water and overcomes some of the wash retarding effects of hardener. Processing times vary by product, but all washing aids dramatically reduce the archival washing time, also limiting the potential loss of optical brighteners from the paper.

Water replenishment over the entire paper surface is essential for even and thorough washing. Washing a single print in a simple tray, with just a running hose or an inexpensive Kodak Print Siphon clipped to it, is effective archival washing, as long as the print remains entirely under water, but washing several prints this way would take an unreasonably long time. When many prints require washing at the same time, it is more practical to use a multi-slot vertical print washer, such as those made by Calumet, Gravity Works, Nova, Zone VI and many others. They segregate the individual prints and wash them evenly, if the correct water flow rate is controlled effectively. However, water flow rates can be kept relatively low, since the rate of diffusion is the limiting factor of thiosulfate removal. The flow of water only needs to be sufficient to replace the entire volume of water every 5-8 minutes. Increasing water flow will not speed up print washing but may introduce unwanted turbulence patterns, which will cause uneven print washing!

Be aware of a few pitfalls, when using a vertical print washer. The emulsion side of the paper can stick to the smooth wall of the washing chamber, or dividers, and never get washed! Only use textured dividers in vertical print washers, and make sure that the textured side is always facing the emulsion side of the paper. Also, most print washers have dividers tall enough to be head and shoulders above the water level. When a print is submerged, some excess fixer is caught on the top edge of these dividers and is inadvertently wiped onto the clean print again when it is pulled from the wash. Hose down the top edge of the dividers after a print is inserted, to avoid its re-contamination.

Washing efficiency increases with water temperature, and a range of 20-27°C (68-80°F) is considered to be ideal. Higher washing temperatures will soften the emulsion beyond safe print handling. On the other hand, if you are unable to heat the wash water, and it falls below 20°C (68°F), the washing time should be increased, and the washing efficiency must be verified through testing. Avoid washing temperatures below 10°C (50°F). Also, research by other authors indicates that washing efficiency is increased by water hardness. Soft water may be good for household plumbing, but it is not a good medium for print washing.

### Testing Washing Efficiency

Residual thiosulfate, left by the washing process, can be detected with Kodak's HT2 (hypo test) solution (fig.11). The test solution is applied for 5 minutes to the damp print border. The color change is an indicator of the residual thiosulfate level in the paper. Compare the color stain, caused by the test solution, with fig.12 to estimate the residual thiosulfate levels and their limits to satisfy archival standards. HT2 contains light sensitive silver nitrate. Consequently, the entire test and its evaluation must be conducted under subdued tungsten light. If you need to keep your tests for later evaluation, rinse the test area in salt water to stop further darkening.

We also recommend verifying the evenness of your print washing technique with a whole test sheet. Fix and wash a blank print, noting the washing time, water temperature and flow rate. Apply the test solution to the wet sheet in five places, one in each corner and one in the center. After 5 minutes, compare the spot colors with the chart in fig.12, and compare their densities as an indicator for even washing.

The washing efficiencies in fig.10 are our own test results, based on research by Martin Reed of Silverprint and published in his article ‘Mysteries of the Vortex’ in the July/Aug and Nov/Dec 1996 edition of *Photo Techniques*. The test chart in fig.12 is based on a Kodak original, but the stain colors are based on our own research with currently available chemicals and papers. In these investigations, we also measured the washing performance of prints fixed in alkali and acid fixers of similar thiosulfate concentrations, with and without a consecutive treatment in washing aid. In all cases, prints fixed with alkali fixer, followed by just a plain wash, had the same washing performance as prints fixed with acid fixer and treated in washing aid.

## Image Stabilization

Agfa markets a silver-image stabilizer product called ‘Sistan’ (fig.13). It contains potassium thiocyanate, which provides protection, in addition to toning, in two ways. First, it converts residual silver halides to inert silver complexes, and while remaining in the emulsion, it converts mobile silver ions, created by pollutants attacking the silver image, to stable silver thiocyanate during the print’s life. The resulting silver compounds are transparent, light insensitive and chemically resistant thus protecting the image beyond toning. Alternative products are Fuji AgGuard and Tetenal Stabinal. Their main ingredients are different from Sistan’s, to which our experience is limited.

Silver image stabilizers are applied in a brief bath after archival washing. After this treatment, the print is not to be washed again. The stabilizer solution remains in the emulsion ready to react with any oxidized silver to prevent discoloration. Silver image stabilizers are not a replacement for toning, but offer additional image protection.

## Print Drying and Flattening

With the conclusion of the last wet process, the print is placed onto a clean and flat surface draining into the sink. Any excess liquid must be safely removed from both sides of the print to avoid staining. A window squeegee and an oversized piece of glass from the hardware store make perfect tools for this step. However, for safe handling, the glass must be at least 1/4 inch, or 6 mm, thick, and all sharp edges must be professionally ground to protect your hands and fingers from nasty cuts. In addition, make sure that your hands and equipment are clean at all times, and handle the print slowly and carefully. The paper and emulsion are extremely sensitive to rough handling while wet, and kinks and bends are impossible to remove.

To dry prints sensibly, place FB prints facedown, and RC prints faceup, on clean plastic-mesh screens. RC prints dry easily within 10 minutes at ambient temperatures. FB prints are dried either at ambient temperatures, within 2-4 hours (fig.14), or in heated forced-air industrial driers within 30 minutes. If space is at a premium, hang the prints on a line to dry. Use wooden clothespins to hold them in place, but remember that these will leave minor pressure marks and possible contamination on the print. Consequently, this method requires that the print be trimmed before mounting or storage. Film hangers or plastic clothespins will not contaminate the print, but depending on their design, may leave objectionable pressure marks or trap humidity.

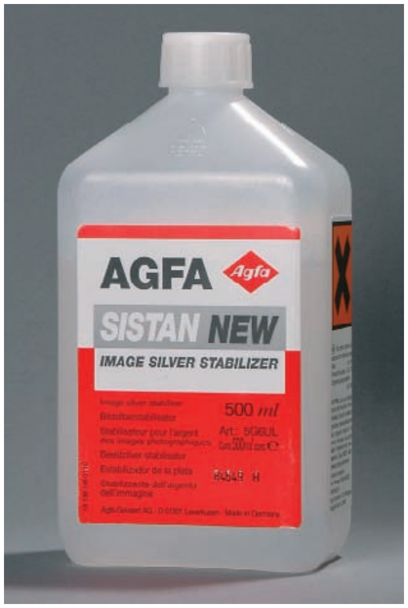


fig.13 Agfa’s silver image stabilizer

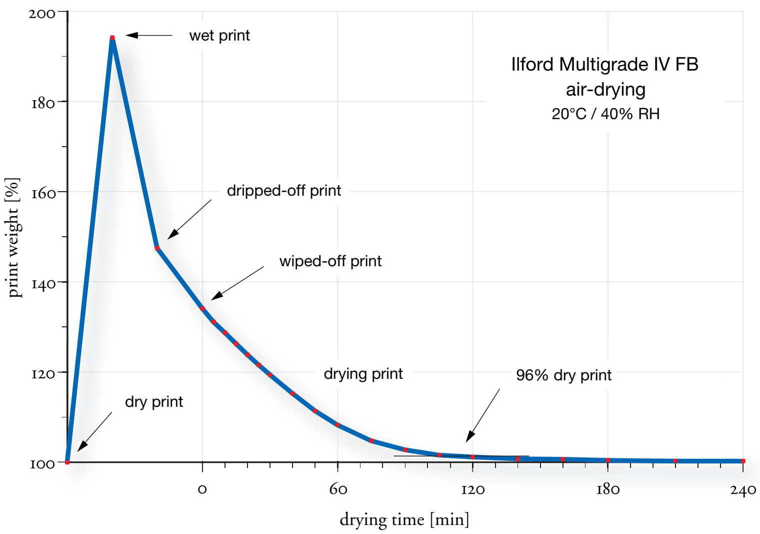


fig.14 A dry print soaks up enough liquid to almost double its weight, while going through wet processing. Simply letting excess liquid drip off, for a few seconds, loses about half of that weight gain, and a final wipe reduces it further. The remaining damp print dries within 2-4 hours at normal ambient conditions.

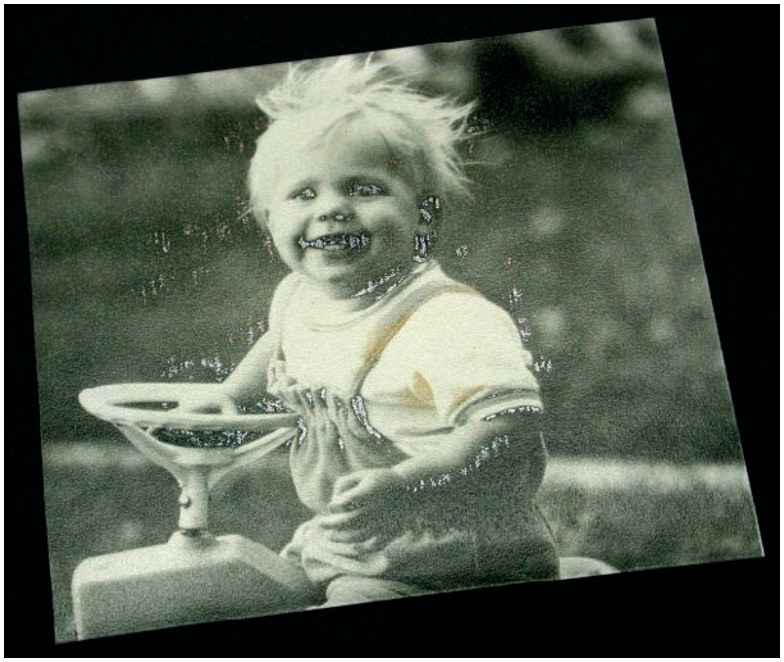


fig.15 This untoned, and therefore unprotected, RC print shows significant signs of discoloration after only 17 years.

After drying, RC prints lay extremely flat, but FB prints have an unavoidable, natural curl towards the emulsion side of the paper. The amount of curl differs by paper brand, but if considered intolerable, it can be reduced with some attention to the drying technique applied. Dry prints at ambient temperatures, because curling increases with drying speed (and toned images may lose color). Place FB prints facedown to dry, as the weight of the wet print works against the curl, or hang two prints back-to-back with clothespins at all four corners, as the two curls will work against each other.

The techniques above will reduce, but not eliminate, the natural curl of FB prints. To store or mount prints, further print flattening is often required. One simple and moderately successful method is to place dry prints individually, or in a stack, under a heavy weight for a day or two. A thick piece of glass, laden with a few thick books, makes for an effective weight without contaminating the prints. Another outstanding and expeditious practice to flatten numerous dry prints is to place them sequentially into a heated dry-mount press, for a minute or two, and then, leave them to cool under a heavy sheet of glass for several minutes.

An alternative approach is to utilize gummed tape and affix the still damp print to a sheet of glass, where it is left to dry. This type of tape can be purchased wherever framing supplies are sold, as it is also used for matting prints. For this technique to work, print the image with a large white border, and wipe the print, front and back, to remove any excess liquid. Place the print faceup onto the clean sheet of glass, moisten a full-length piece of tape and secure one print border to the glass. Repeat this for the remaining print borders and leave the print to dry overnight. The next day, cut it loose and remove the taped borders by trimming the print. While drying, the shrinking paper fibers are restrained and stretched by the tape, leaving a perfectly flat print, ready for storage or presentation.

## Print Deterioration

From the instant of its creation, a silver-based image faces attack from a variety of sources. Some are internal and essential to the materials photographic papers are designed and manufactured with. They come in the form of chemicals, inherent or added to the paper, the emulsion or the coating. They either are a fundamental part of the paper characteristics or meant to improve them.

Other sources of attack are of external origin. Nevertheless, some are intrinsic to the photographic process and can be minimized but not completely avoided. Most processing chemicals fall into this category. In the very beginning of a print's life, and only for a few minutes, we need them to be present to complete their designated tasks. Beyond that point, we like to rid the print of them quickly and entirely. Fortunately, these sources of image deterioration are under our control, but no matter how attentive our work might be, unavoidable traces of them will remain in the print forever, and given the right environmental conditions, they will have an opportunity to attack the very image they helped to create.

The remaining extrinsic sources of image attack are hiding patiently in our environment, ready to start their destructive work as soon as the print is processed and dry. They can broadly be separated into reducing and oxidizing agents. Roughly until the introduction of the automobile, reducing agents were the most common sources of image deterioration. Then, oxidizing agents like aldehyde, peroxide and ozone took over. Their presence peaked in the Western World around 1990 and fortunately began to decline since.

The print in fig.15 illustrates common contemporary image deterioration. It is a photograph of Ralph's 10-month-old daughter, Alyssa. This RC print spent 17 years framed under glass, partially covered by an oval overmat and displayed in an interior hallway, away from direct sunlight. Where protected by the mat, it is fine, but where exposed to light, image discoloration is clearly visible. This is due to oxidation of the metallic image silver, caused either by internal oxidants from poor washing or by environmental gases, as found in atmospheric oxygen, ozone, curing paint and adhesive, new carpet, fossil fuel fumes, the resins from processed particle board and unfinished wood.

Image oxidation follows a pattern. Initially, image silver is oxidized into silver ions. Then, these mobile silver ions, supported by humidity and heat, migrate through the gelatin layer and, when the concentration is high enough, accumulate at the gelatin surface. Finally, the silver ions are reduced to silver atoms, which combine to colloidal silver particles. They are brownish in color, as seen around the shoulder strap, but at the print surface and viewed at a certain angle, they are visible in the form of small shiny patches. This more advanced defect is referred to as 'mirroring', and it occurs exclusively in the silver-rich shadows of the print.

There is evidence that RC prints are more susceptible to image oxidation than FB prints. One possible reason is that the polyethylene layer between emulsion and paper base in RC prints keeps the mobile silver ions from dissipating into the paper base, as they can in FB prints. In RC prints, the ions are more likely to travel to the emulsion surface, since they have no other place to go. Another reason for RC image oxidation is that light absorption by the titanium dioxide pigment in the polyethylene layer can cause the formation of titanium trioxide and oxygen. This will increase the rate of silver oxidation if the prints are mounted under glass, preventing the gases from escaping. As a preventive measure, modern RC papers made by the major manufacturers contain antioxidants to reduce the chance of premature oxidation. Proper toning and image stabilization practice will help to protect against image deterioration!

## Print Storage

Besides emphasizing the importance of careful processing, the print in fig.15 also illustrates the difference between light and dark storage in regard to print longevity. It takes little imagination to still make out the border of the removed oval overmat. A print stored in the dark has a much longer life expectancy than a print stored in similar temperature and humidity conditions but exposed to light. Therefore, prolonged exposure to light, and especially ultraviolet radiation, presents one of the dangers to print survival. This does not mean that all prints must be stored in the dark and should never be displayed, but it does mean that all prints destined for long-term display must be processed with the utmost care, and the print in the family album is more likely to survive the challenges of time than the one exposed to direct sunlight. However, the latter may not be true if the album is made from inferior materials or is stored in an attic or a damp basement, because other significant dangers to print longevity are the immediate presence of oxidants, non-acid-free materials and extreme levels and fluctuations of humidity and temperature.

A summary of the most important processing, handling and storage recommendations follows. Simple, reasonable care will definitely go a long way towards image stability and longevity.

**Print Processing, Handling and Storage Recommendations**

1. Prints should only be processed in fresh chemicals. Without exception, they must be well fixed, protectively toned, thoroughly washed and stabilized.
2. Minimize print handling, and always protect finished prints from the oils and acids found on bare hands by wearing clean cotton, nylon or latex gloves. Avoid speaking while leaning over prints.
3. Store valuable prints in light-tight, oxidant and acid-free storage containers, or mount them on acid-free rag board, protected by a metal frame and glass, if destined for frequent display.
4. The storage or display environment must be free of oxidizing compounds and chemical fumes. Before redecorating a room (fresh paint, new carpet or furniture), remove prints and store them safely elsewhere for at least 4-6 weeks, before they are brought back.
5. Store or display prints at a stable temperature at or below 20°C (68°F) and at a relative humidity between 30-50%. Do not use attics (too hot) or basements (too damp) as a depository for photographic materials. Store prints in the dark, or when on display, minimize the exposure to bright light to the actual time of exhibition, and always protect them from direct exposure to daylight.

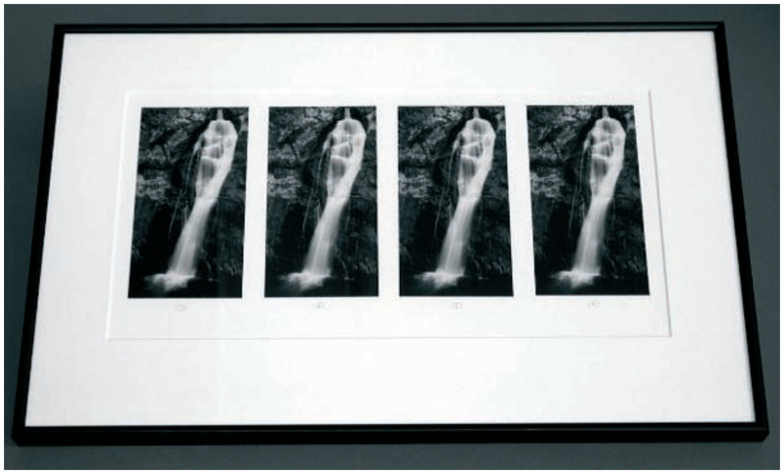


fig.16 Four prints were produced from the same negative. They were treated differently to test for archival influence of various processing steps. They were all mounted and framed within an hour and are constantly exposed to natural light. This test is likely to last several decades.

| processing step | print | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| **Developer**<br>Dektol 1+2 | 90 s | | | |
| **Stop Bath** | 30 s | | | |
| **1st Fix**<br>Hypam 1+4 | 20 s | 45 s | | |
| **2nd Fix**<br>Hypam 1+4 | - | 45 s | | |
| **1st Wash** | 1 min<br>(5°C) | 4 min<br>(25°C) | 2 min<br>(25°C) | |
| **Toner**<br>Selenium 1+19 | - | | 1 min | 6 min |
| **2nd Wash** | - | | 4 min<br>(25°C) | |
| **Stabilizer**<br>Sistan 1+39 | 60 s<br>(lower half only) | | | |

fig.17 Different processing steps provided prints ranging from poorly processed and unprotected to well processed and well protected.

Our print storage recommendations above are not nearly as strict as standard operation procedures for a museum, conservation center or national archive would demand. Nevertheless, they are both practical and robust enough to be seriously considered by any discerning amateur willing to protect, and occasionally exhibit, valued prints at the same time. A concerned curator is obliged to verify that all photographic enclosures meet the specifications of ANSI/PIMA IT9.2-1998 and that they have passed the Photographic Activity Test (PAT), as specified in ANSI/NAPM IT9.16-1993. Regular consumers can contact their suppliers to confirm that their products satisfy the above standards.

## Image Permanence

Archival processing is preparation for an unknown future. If it is done well, the print will most likely out-last the photographer who processed it. On the other hand, if it is done carelessly, or just plain sloppily, then the print may look fine for years, or decades, before deterioration suddenly becomes evident. There is research evidence that modern environmental conditions can shorten the life of a print, even when processed perfectly. And of course, we have no idea how the chemical cocktail of future environments will affect new and old silver-based images, making any prediction about a print's potential life expectancy problematic, or at best, demoting them to professional guesswork. Also, the print's long response time to processing errors or environmental attack makes reliable process and storage instructions difficult, if not impossible, and all too often highly argumentative. We can only build on the experience of previous photographic generations and combine this with reasonable disciplines, which are based on the current understanding of the underlying chemical and physical principles. That is the purpose of this chapter and the most sensible way to deal with image protection and permanence.

Nevertheless, a few simple experiments can give some insight to the severity of processing errors and to the effectiveness of recommended preventions. Fig.8 illustrated a standard bleach test to verify toning efficiency, and fig.16 shows a long-term experiment in progress, involving four identical RC prints, made from the same negative but with very different processing details after development and stop bath (fig.17).

**Print 1** is the result of an attempt to create a worst-case scenario by processing the image as poorly as possible. The time in exhausted fixer was clearly too short to remove all residual silver halides, and the brief cold wash is highly unlikely to have removed enough thiosulfate to secure any reasonable image stability. We expected this print to be the first to show signs of deterioration. **Print 2** represents finest commercial processing. The residual silver was properly removed with two fixing baths, and the warm wash was long enough to reduce thiosulfate levels to acceptable amounts for an RC print. However, no subsequent protective sulfide or selenium toning was performed, which leaves the image silver without any protection against environmental influences.

**Print 3** has the additional benefit of a mild selenium toning and an even longer wash without over-washing. Assuming current wisdom to be correct, this print should have a life expectancy of several decades, outperforming color photographs displayed under similar conditions. **Print 4** goes a step further by increasing the toning time to a point where even the highlights experience a visible color change. Esthetically, this is not everybody's taste, but from an archival viewpoint, it promises increased print protection. One can only do better with the previously mentioned combination toning, using both sulfide and selenium to fully protect all print tones and using FB papers.

As a final processing step, the bottom half of all prints were treated in Agfa Sistan. This test is designed to eventually reveal the effectiveness of silver-image stabilizer protection for poorly and well-processed prints. Until then, we highly recommend them for RC and FB prints. The prints were mounted and matted with acid-free museum board and framed under glass within an hour from processing. The following day, they were displayed on a windowsill, facing out and south, where they have been ever since.

These prints were processed, mounted and framed in January 2001. Since then, they received a daily exposure to sunlight and seasonal temperature fluctuations. In early 2008, the highlights in the upper half of print 1 developed a hardly visible, light-brown stain. At the time of this writing, in January 2010, these highlights are clearly stained, and print 2 shows a similar deterioration but to a much lesser degree. However, in each case, there is a sharp dividing line to the lower half of the print, which was treated in Sistan and shows no sign of degradation. Print 3 and 4 look as well as they did the day these prints were made.

This test is no proof that toned prints (3 and 4) will last forever, but it does verify that a badly fixed and washed print (1) has only a short life expectancy. It also indicates that otherwise proper print processing, but without the protection of toning (2), is not enough to promise reasonable image stability. This test will be continued to evaluate the difference in image protection between light (3) and full (4) toning, and the test may also reveal how long Sistan is able to protect poorly processed RC prints.

Print deterioration is a quietly ticking time bomb. There may be no visible evidence for years, or even decades, but the unstoppable damage is slowly and secretly progressing inside the emulsion layer. As soon as the first signs of decay become perceptible, the cherished print will quickly lose its initial appeal and may only be kept as a record or for its sentimental value. Once the damage is done, it is impossible to repair it. An ounce of prevention is worth a pound of cure.

## Additional Research

Obtaining assurances and reliable longevity statements from photographic manufacturing companies is difficult, although Crabtree, Eaton, Muehler and Grant Haist of Kodak, have published maximum fixer capacities for commercial and archival printing.

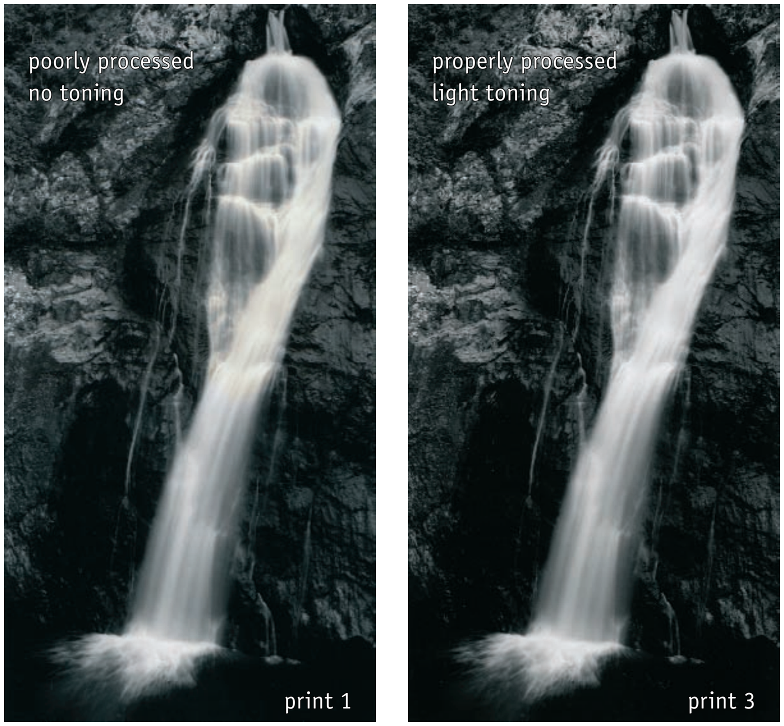


fig.18 After being framed behind glass for nine years, with daily exposures to sunlight and seasonal temperature fluctuations, residual chemicals, left behind by poor fixing and washing, created an unsightly yellow stain in the upper half of print 1. Proper print processing and light selenium toning protected print 3 from the same kind of print deterioration. However, print 1 shows a sharp dividing line between the upper and lower half, which was treated in Sistan and exhibits no sign of degradation.

Valuable information also comes from more recent research reported by Larry H. Feldman, Michael J. Gudzinowicz, Henry Wilhelm of the Preservation Publishing Company, James M. Reilly and Douglas W. Nishimura of the Rochester Institute of Technology (RIT) and the Image Permanence Institute (IPI) and by the ISO Working Group. Leading photographers have publicly challenged some claims for silver image stability. Nevertheless, their findings also show that silver image stability is improved with two-bath fixing, toning, thorough washing and the final application of an image stabilizer.

The research on silver image stability will continue. However, past findings have often been proven wrong and improved. Unfortunately, questionable advice has often turned into persistent myth. Ironically, the most vocal companies claiming high archival print standards are those offering inkjet products. Although current inkjet prints cannot outlast an archivally processed FB print, these companies continue to claim for their products to have a lifetime similar to Leonardo da Vinci's sketchbook. Our tests prove these claims to be unreliable, with carbon-based monochrome prints visibly fading within six months.

Claims of archival lasting prints are based on accelerated testing and not actual natural age. Accelerated testing is usually run under high humidity, high temperature and high light levels. These tests may serve as an indicator and comparator, but it would be naive to expect reliable, absolute print life predictions from their results, even though current lifetime predictions are typically based on accelerated testing and the results are prone to interpretation. This is especially true of monochrome prints made with colored inks, for the brain can detect even the most subtle change in image tone with ease.

We cannot claim that our advice or current wisdom is the final word in archival print processing. However, we are confident that processing a FB print according to our recommendations will significantly increase its chance for survival, while protecting the memories and feelings it has captured. RC prints definitely benefit from similar procedures, and modern RC papers, made by Ilford and others, rival the stability of FB papers. However, until we have the true, actual natural-age data for resin-coated papers to confirm their stability, fiber-base papers remain the best choice for fine-art photography.

## Review Questions

1. Which of the following is true about f/stop timing?
    a. requires a dedicated enlarger timer
    b. makes better prints
    c. only works in combination with print maps
    d. creates test strips with even exposure increments

2. Which of the following is true about print contrast?
    a. is controlled by print exposure
    b. is independent of paper surface
    c. is the density difference between highlights and shadows
    d. should be controlled with development time

3. What are the characteristics of a properly exposed print?
    a. the highlights have the correct appearance
    b. all shadows show sufficient detail
    c. the highlights are pure white
    d. the midtones are 18% gray

4. What is dodging and burning used for?
    a. to rescue a print
    b. to emphasize image features and optimize print appearance
    c. to change the contrast with fixed-grade papers
    d. not required with perfect negatives

5. Which of the following is false?
    a. fix as long as you must but as short as you can
    b. incomplete fixing can be detected with sulfide toner
    c. selenium and sulfide toning improve print longevity
    d. the purpose of washing is to remove all residual fixer

6. Which of the following is the best practise for archival processing?
    a. two-bath fixing
    b. the use of hypo eliminators
    c. soak prints overnight in running water
    d. a water softener should be used to reduce wash times

7. Which is the most reasonable print storage recommendation?
    a. store prints as cold as possible, freezing them is best
    b. store prints in the dark and only present them in dim light
    c. use a protective spray and seal prints in plastic envelopes
    d. store at 20°C between 30-50% humidity in acid free containers

1d, 2c, 3a, 4b, 5d, 6a, 7d

© 2004 by Ralph W. Lambrecht, all rights reserved

# Presentation Is Everything

This page intentionally left blank

# Mounting and Matting Prints

## Solid steps to successful print presentations

In addition to supporting and protecting the print, the main function of the mount is to isolate the print and clear the immediate image surroundings from visual distractions (fig.1), thereby providing an aesthetically pleasing, neutral and complementary viewing environment, without any attempt to compete with the image for attention. A truly successful image can probably stand on its own, but even the best image benefits from appropriate presentation, if we want to portray its full potential. A properly mounted, matted and framed print has clear advantages over its loose counterpart, including focused communication, the perception of increased value, some protection against rough handling and optimized longevity. When processed to archival standards and competently mounted with quality materials, an appropriately stored and displayed print can be admired for several lifetimes.

### Description

Fig.2 shows the basic components of mounted artwork ready for framing. First, the print is securely attached to the mount-board using dry-mount adhesive or suitable alternate means. Then, the mounted print is covered and protected with a window overmat, as well as supported by a backboard. The difference between mounting and matting board is in the way they are applied, either carrying or overmatting the print, but some manufacturers make significant material differences between the two. Unless, for creative reasons, you cannot live without a color or texture difference between mount-board and overmat, I suggest using the same material for both to give the print consistent protection and appearance.

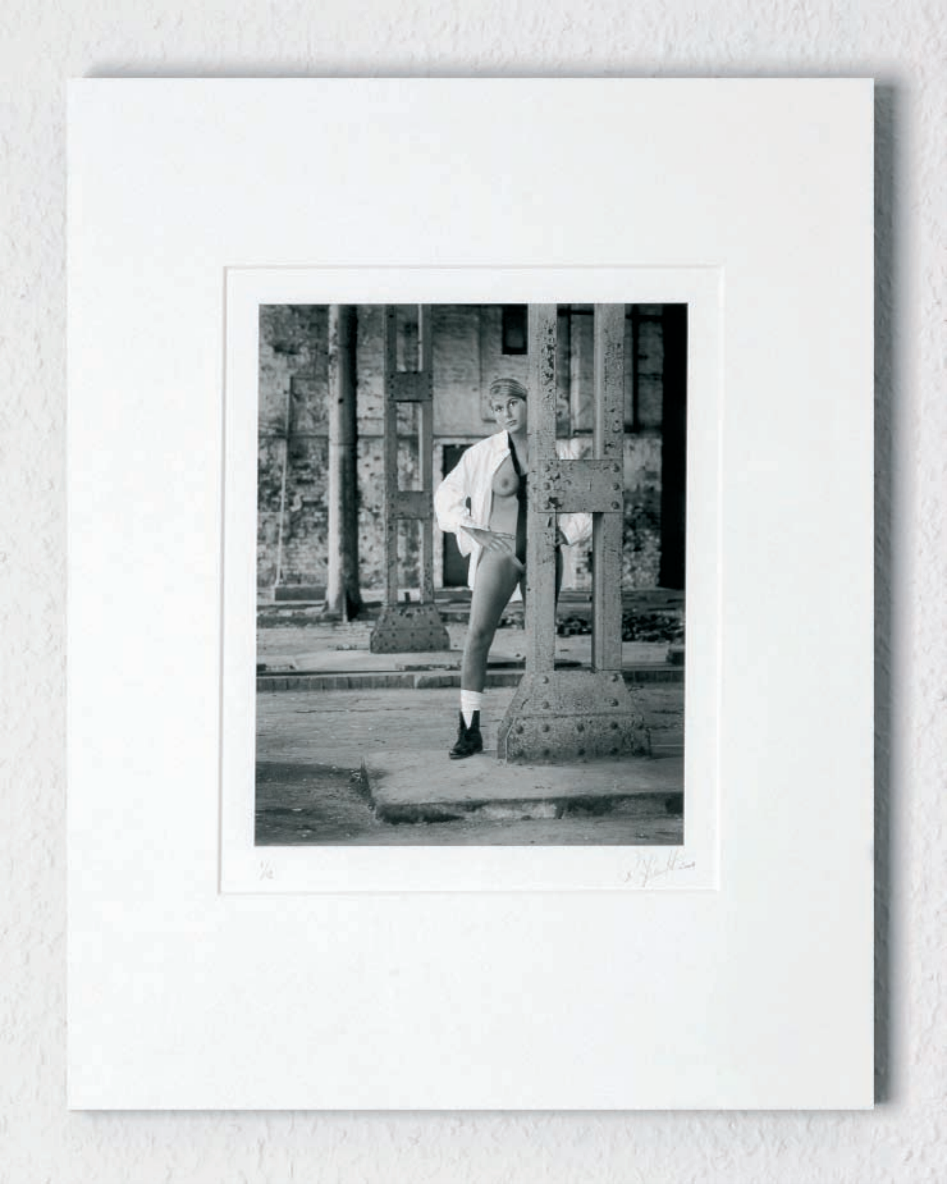


fig.1 The mount supports and protects the print, while clearing the immediate image surroundings from visual distractions, without competing for attention.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50008-9

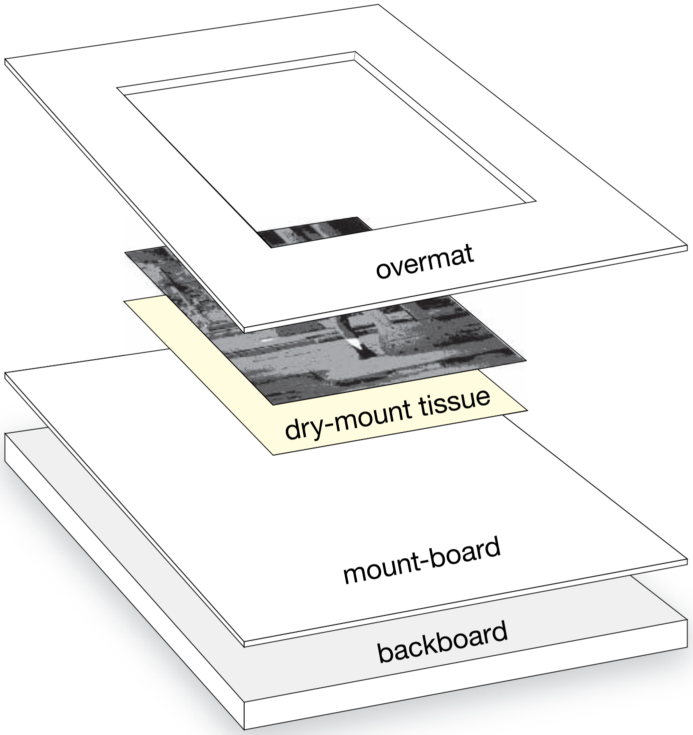


fig.2 The basic components of dry-mounted artwork ready for framing. The print is securely attached to the mount-board, using an adhesive tissue or film. The mounted print is then covered and protected by a window overmat, and supported with a backboard.

## Mounting Styles

There are various mounting styles to choose from, the selection of which too often depends on the type of presentation and longevity requirements. They all differ from one another in the material choice, the size of the mount-board, the attachment method for the print, a preference for an overmat and the equipment required to put it all together. Some mounting styles aim for the most favorable print presentation and protection, while also providing best possible archival conditions; others just aim to improve short-term print presentation without any claims of permanence. This chapter offers an overview of several mounting styles but concentrates on archival mounting and professional print presentation.

When the print and mount-board are of the same dimensions, it is called a flush or bleed-mount style. This stiffens the prints but offers little protection around the edges. Bleed-mounting also completely fails to isolate the print from potentially disturbing surroundings, because no mount-board is left showing, and as a result, it makes for a rather lackadaisical presentation style. Having said that, I have used bleed-mounting successfully in assembling photographic aids, as shown in ‘How to Build and Use the Zone Ruler’. In all other cases, I prefer a rather wide border around the print, which is referred to as the border-mount style.

To attach the print to the mount-board, we have the option of creating a permanent bond or just loosely holding the print in place and securing its location later with an overmat. Both methods have pros and cons, so before we decide, let us explore each in more detail.

A permanent bond always requires some kind of an adhesive. Stay well away from liquid or spray adhesives. They are extremely messy, make a smooth bond a matter of chance and rarely have any archival properties. Dry adhesives are far better, and there is the choice between cold and hot dry-mounting, which both use an adhesive tissue or film. Dry-mount adhesive, once applied, creates an irreversible bond and acts as a protective layer between mount-board and print. This layer protects the backside of the print from any environmental contamination coming through the backboard and potentially being absorbed by the mount-board, leaving only the print’s image area exposed to air-born contaminants.

In cold dry-mounting, the adhesive is laid upon a release layer and then rolled onto the back of the print. Full adhesion only comes through the application of pressure. The adhesive does not come off on your hands and makes for clean, odorless working. However, the classic permanent bond is only accomplished through hot dry-mounting (see fig.14). It requires the use of an expensive dry-mount press, which securely sandwiches the dry-mount adhesive between the mount-board and the print under pressure, while applying enough heat to melt the adhesive. Some of the molten dry-mount adhesive is then absorbed by the surface fibers of mount-board and print, forming a permanent and waterproof bond between them, once the adhesive has been given enough time to cool and solidify. Dry-mounting makes for a perfectly flat mount with an unrivaled professional look. It is clean, dependable, fully archival, and every serious fine-art photographer is well advised to seriously consider this method. Unfortunately, some print materials do not react well with the heat, and then, the use of cold-mount adhesive might be the better option. Nonetheless, hot dry-mounting is my preferred choice for mounting FB-prints.

There might be one good reason not to dry-mount at all, if your prints are destined for a salon or gallery showing. The person in charge of the exhibition may simply not accept dry-mounted prints. Galleries often present the works of more than one artist and may insist on consistency of presentation between images. To ensure this, they need the flexibility of remounting and reframing your prints at will. The permanency of a dry-mounted bond does not allow this flexibility. To maintain the option of selecting a different mount in the future, we need to select a reversible mounting method. Two different methods are commonly used, hinge-mounting and corner-mounting.

To hinge-mount a print, a piece of tape is used as a flexible hinge; half of it applied to the mount-board and the other half directly to the print. Only use conservation or museum-quality, gummed, acid-free cloth tape with a water-soluble adhesive. Self-adhesive tape is not acceptable, as it can dry out and eventually fail. Of course, the print should feature a white non-image border to provide some room for the tape. The overmat then covers tape and border.

To corner-mount a print (see fig.16), small corner pockets of acid-free paper are taped to the mount-board, holding the print loosely at all four corners. As with hinge-mounting, the print should feature a white border, so the corner pockets do not infringe into the image area, and the overmat covers the corners, tape and border. Hinge-mounting is simpler, but for non-permanent mounting, I prefer corner-mounting, because it leaves no tape residue on the print and makes freeing it from the mount as simple as slipping it carefully out of the paper pockets.

**Mounting board**, **matting board** and **backing board** are terms referring to the 'raw' stationery materials used.
**Mount-board**, **mat-board** and **backboard** are usable sheets, cut to size from the above stationery materials. Cutting a window opening into a mat-board turns it into a functional 'window' **overmat** or just a **mat**.
**Mount** is a general term, referring to the mounting style or the entire assembly but without the frame.

If the print is dry-mounted and you prefer a plain mount, the mounting effort is finished at this point. Unfortunately, we need to consider that the mounted print has been raised off the mount-board by the combined thickness of the dry-mount adhesive and the print paper itself. This makes the print edges vulnerable to damage from handling and stacking. Therefore, before a mounted print is framed and put behind glass, an overmat with its window opening must be cut and placed on top of the mount-board. This will protect the print from irreparable damage and keep it from rubbing or touching the inner glass surface, allowing it to 'breathe' and circumvent the emulsion from sticking to the glass over time. Furthermore, to keep the overmat securely aligned with the print, it helps to hinge-mount it on one side to the mount-board, using acid-free cloth tape. The additional overmat raises the optical appeal of the print. Consequently, an overmat should be considered for both framed and unframed prints alike, in order to make for the finest print presentation possible.

To give this mounting arrangement an even more pleasing look, it is customary to cut the inner window, exposing the print, with a bevel cutter. The resulting bevel joins the mount-board and overmat smoothly at an angle between 45° and 60°, eliminating harsh and distracting shadows, yet framing the print delicately. The size of the window opening depends on the type of print attachment used. If the print is hinge or corner-mounted, the window needs to be smaller than the image area of the print to cover the tape, corner pockets and print border, and to hold the print firmly in place. If the print is dry-mounted, you have some flexibility in choosing the window dimensions. I cut my windows large enough

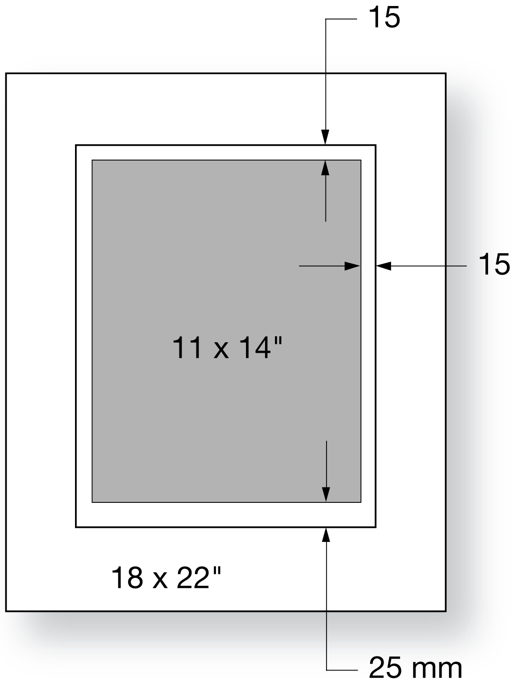


fig.3 To enhance the print presentation and protect the print from physical damage, an overmat with its window opening is prepared and placed on top of the print and mount-board. For a dry-mounted print, the window is cut large enough to provide clearance on all sides of the print. Below the print, a bit more space is needed to allow enough room for print edition number, signature and date.

to provide about 5/8-inch (15 mm) clearance on the sides and on top of the print (see fig.3). Below the print bottom, I allow a bit more space, sufficient to add the print edition number, and to sign and date the print later. I find 3/4 to 1 inch (20-25 mm) to be adequate for that task.

Before deciding which prints to mount and what style to choose, consider that quality print mounting takes time, effort and money, and not every print deserves this treatment. However, if the value of an individual image was mirrored by your choice of print materials and was processed to archival standards, then it makes sense to continue this standard through the mounting and presentation steps. I only mount my best prints, which are targeted for exhibition or sale, and I do it just prior to these events, using only the best materials. It takes less space to store loose prints in archival boxes until they are needed. Mounting valuable prints is a presentation technique, not a storage method. I use RC paper only for preliminary work, such as artwork for magazines or as a give-away for model portfolios. Consequently, I do not mount RC prints. Nevertheless, it can be done if you prefer RC prints, and the techniques described in this chapter work for FB and RC prints alike.

## Mounting Materials

Board is manufactured from different paper materials to support varying archival requirements and budgets. Regular illustration board or standard board is made of virgin cellulose fibers (wood pulp). It contains lignin, which forms the cell walls in plants. Untreated, this material contains acid (pH<7.0) and is, consequently, harmful to silver-gelatin prints. Over time, lignin and acid will degrade the artwork. Standard board discolors visibly within a few years, accelerated by temperature, humidity, pollution attack and exposure to light. This can typically be seen at the beveled edges first. Illustration or standard board is a low-budget material and not recommended for our treasured prints.

Conservation board is made of alpha-cellulose wood pulp, which has been chemically treated to eliminate acid and lignin. It gives artwork a higher degree of protection, and FB paper itself is made of this acid-free material. Conservation board is a good choice for photographic prints, providing a professional finish and a minimum level of archival protection. These benefits justify the increase in cost.

Museum board or cotton-rag board is made of 100% cotton fibers, which are naturally acid-free and lignin-free. The term 'rag' dates back to the time when

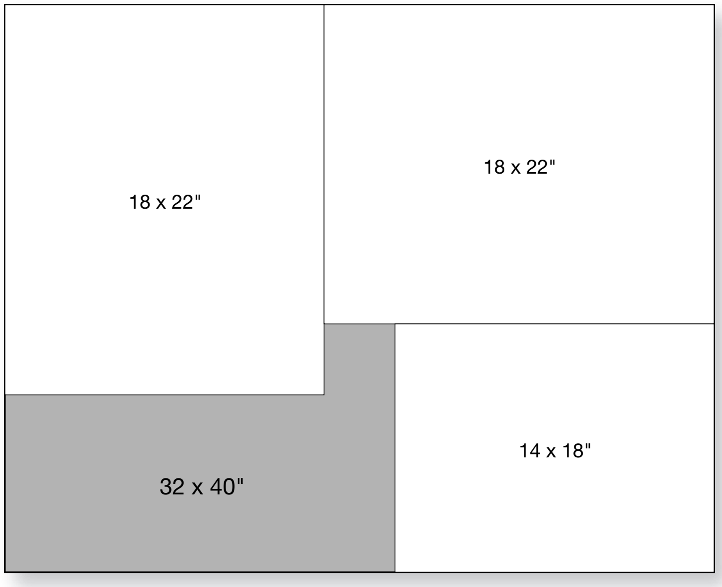


fig.4 Mounting and matting board comes in a variety of full-sheet sizes, with 32x40 inches being the most common dimensions. It is advisable to prepare cutting plans for your favorite mountboard dimensions to minimize waste. Two examples are shown here.

cotton rags and cloth were the principal materials used for paper manufacture. Cotton is a time-tested, fade-resistant and durable material, offering the highest level of archival protection. It is used by museums and discerning photographers for the preservation of fine prints. The inherent expense should not stop us from using it for prints of high value.

As an alternative to the choices above, some manufacturers offer 'buffered' boards. Buffering, or pH-balancing, is an additional fiber treatment to neutralize acid, which might be generated in the future from aging prints or boards, or from environmental pollution. A buffered board or paper has calcium carbonate added to the fibers, which provides an alkaline reserve (pH7.5-9.5), just waiting to counterbalance any potential acid attack in the future. Buffered materials are a good choice, although not in combination with some historic photographic processes, like Cyanotype, because the alkaline environment will actually damage these types of prints.

Dry-mount adhesive is an acid-free, dry acrylic adhesive, available as thermoplastic rolls or sheets in two basic compositions, as tissue or film. Dry-mount tissue has a center carrier of porous or non-porous tissue with adhesive applied to either side of the tissue. Dry-mount film has no carrier tissue at the center; it is pure, non-porous adhesive. Non-porous dry-mount tissue and dry-mount film may trap air or steam between print and adhesive during mounting. This will create objectionable bubbles with RC prints. With FB prints, on the other hand, trapped air has the opportunity to escape through the print. I prefer porous dry-mount tissue, because it works well with both RC and FB prints.

Backing board provides a stiff and flat print support, which is needed to securely frame the mounted artwork. It typically has a rigid foam core, sandwiched between two layers of paper. The foam center is made of extruded polystyrene, an inert and resilient plastic material, which keeps the board light and easy to cut. For archival mounting, the surface papers must be made of the same acid-free and lignin-free material as the mounting and matting board used in order to offer consistent protection. Otherwise, an optional acid-free barrier can be placed between mount-board and backboard, providing additional protection against environmental contamination. Some framers suggest using a sheet of inert plastic or glass as a barrier, but I am concerned that they create a potential humidity trap and recommend using an acid-free paper barrier instead.

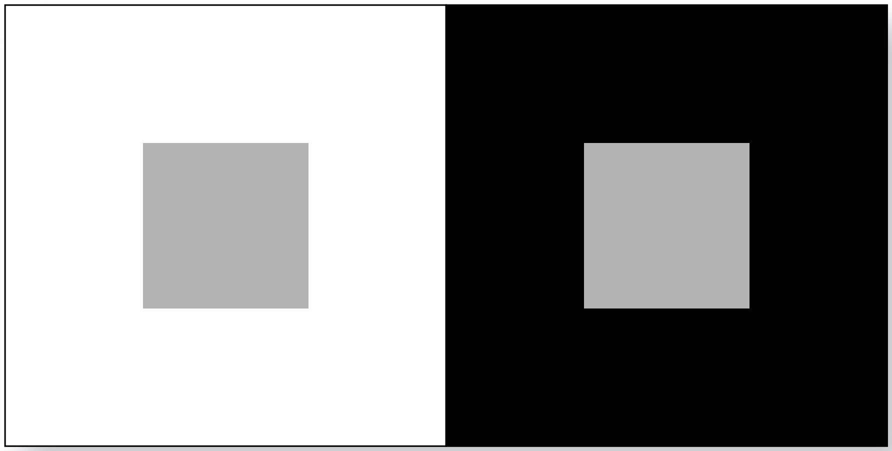
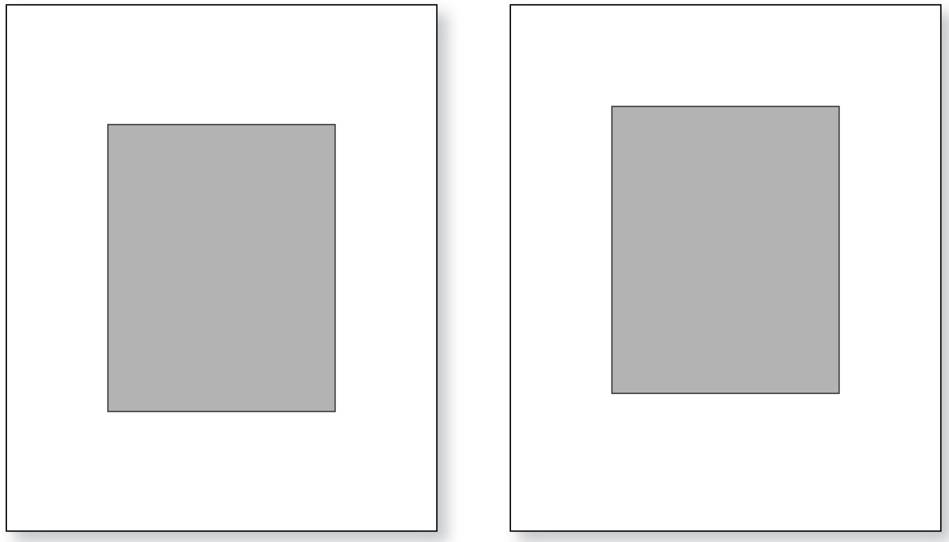


fig.5 Our subjective sensation of reflection density is noticeably influenced by the surroundings of the evaluated sample. A medium gray appears to be darker in the vicinity of white than when surrounded by black.

## Sheet Size and Thickness

Many suppliers offer boards in either standard or custom sizes. The standard sizes are often too restrictive, and the custom sizes are quite expensive. If you have available storage space and the proper equipment, it is more flexible and more economical to purchase the boards in 'full' sheets and cut them to size yourself. Full sheets come in a variety of sheet sizes, with 32 x 40 inches being the most common dimensions, and it is advisable to prepare a cutting plan (see fig.4) to minimize waste. Nonetheless, do not turn prudence into false economy. Select a mount-board size that suits the image, your style and the intended presentation, not the one that gives you the least amount of scrap. Conveniently cutting four 16x20-inch sheets from one 32x40-inch board may illustrate efficient planning but little aesthetic consideration. No one will see your cut-offs, but many will notice an inappropriate mount size. I keep my cut-offs to create useful tools, jigs and spacers for studio and darkroom work.

Mounting and matting board comes in thicknesses of 2, 4, 6 and 8 ply, with 4 ply, which is equivalent to 1/16 inch or 1.5 mm, being the most popular. Galleries and museums often use the thicker boards for large mounts or special effect. Backing board is thicker and varies from 1/8 to 1/2 inch, but not all sizes are available



a) b)

fig.6 It is commonly agreed that a print, centered on the vertical axis, appears to be too low on the mount. This print placement creates an optical illusion that the print is not equally spaced at top and bottom; the print seems to sag below the vertical center (a). To overcome this illusion, alternative print-placement techniques must be considered (b).

in museum quality. Consider also, before you order expensive thick boards, whether your mat cutter can actually cut that thickness. For example, few cutters can handle bevel-cuts in 8-ply boards.

## Color

Selecting an appropriate color for the mounting materials seems largely to be a matter of personal taste and preference. Nevertheless, a few facts should be considered before making a final color choice. As already stated, the mount needs to complement the print without becoming a distraction. As a general rule, this disqualifies the use of colored mounts for B&W prints. There may be the odd exception to this rule to support an intended mood, as I have seen in an exhibition of reenacted Civil War images, where prints were sepia toned and suitably displayed on a light tan mount to imply age. However, most B&W prints are presented on either white or black mount-board, and there have been heated debates as to which is the better of the two options.

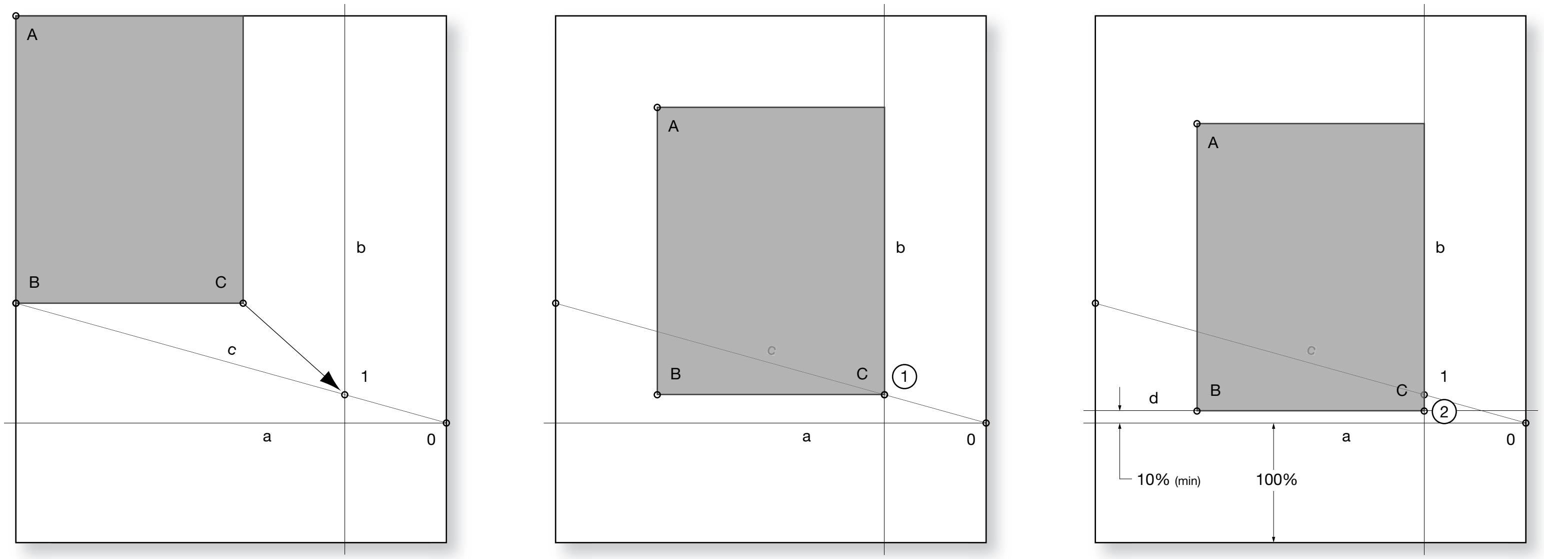
Our subjective sensation of reflection density is noticeably influenced by the surroundings of the evaluated sample. The medium gray in fig.5 appears to be darker in the vicinity of white than when surrounded by black. In fact, all print tones are sensed to be darker on a white mount than they are perceived on a black mount. Consequently, a black mount brings maximum brightness to the highlights but fails to show the full potential of deep shadows. On the other hand, a white mount allows for rich shadows but at the risk of foggy highlights. Neither black nor white seem to be the optimum color choices for skilled B&W print mounting.

As we will see in 'Fine-Tuning Print Exposure and Contrast', the human eye is far more sensitive in detecting reflection density differences in highlights compared to shadows. This presents an obvious solution. Choosing mounting board slightly darker than paper-white creates enough variance for the highlights to be seen as true whites while this tonality change is too minute to detectably degrade the shadows. Selecting even off-white mounting board will improve highlight appearance over the use of bright-white mounts and mats. Although I discourage using black mounting board, I admit that it lifts the highlights of a print, when displayed in dimly lit surroundings, and improves the appearance of poorly printed images containing veiled highlights.

## Mount Size

Assuming a border-mount style, the question of how wide the print-surrounding mount borders and, consequently, how large the whole mount-board should be, needs to be answered. The print mount and frame separates the image from the rest of the wall, adjacent images and the room, allowing the eyes to concentrate exclusively on the image. The dimensions for the mount are mainly a subjective consideration and an indication of the photographer's style or an exhibition's theme. The mount size, nevertheless, also must be a reflection of what is exhibited where.

I prefer some 'breathing space' around the print. Large mount borders seem to raise the visual importance of a print. Small borders offer a more economical look. Really hefty mount borders can look pretentious, but depending on the situation, it sometimes works well. A single 5x7-inch print mounted on an 18x22-inch board inarguably demands a certain level of respect and conveys preciousness. Large exhibition spaces with high ceilings also tend to suit larger mounts, even if the images are small. Brightly colored walls need larger mounts to separate the photograph from that potentially disturbing influence. Images that are not related to those hanging next to them



a) b) c)

fig.7 To find a pleasing print placement, locate the 'optical center' (a), and place the print at that location (b). If this results in the print being too high or too low on the mount, slide it up or down until you reach a more attractive distribution of space, but always maintain a minimum, vertical print offset (c).

require a substantial mount to convey separation. If the exhibition context is unknown at the time an image is mounted, you are less likely to go wrong with a good-sized mount. As a rough guide, consider a 3-inch mount border as a minimum and 4 inches as standard, but do not hesitate to claim 6 inches or more, if it suits the print and its presentation.

## Print Orientation and Placement

Since it is one of the most important functions of the mount to visually isolate the print, optimum print orientation and placement consists of properly apportioning the space around the print. Most photographers, unless specializing in landscapes, produce the majority of their images in a vertical print composition. Generally, the presentation mirrors the print: vertical presentation for vertical prints and horizontal presentation for horizontal prints. Horizontal prints, however, can also be successfully mounted on vertical mount-boards, especially when exhibited within a panel, dominated by vertical prints on vertical mounts. Square prints call for a vertical mount-board orientation more often than not.

Unless you are aiming for a very special effect, there is little argument against placing the print centered on the horizontal axis of the mount. However, attractive print placement on the vertical axis requires a closer look into optimum print isolation and subjective preferences.

It is commonly agreed, and obvious even to the most untrained observer, that a print centered on the vertical axis appears to be too low on the mount. This print placement creates an unfortunate optical illusion that the print is not equally spaced at top and bottom (see fig.6a). In other words, the print seems to sag below the vertical center. To overcome this illusion, alternative print-placement techniques must be considered (see fig.6b).

One accepted technique involves placing the print near the 'optical center' of the mount (fig.7a-b). This makes for an attractive print placement in most situations. To find this optical center, align the upper left-hand corners of the print and mount-board in point 'A'. Now, bisect the remaining spaces to the bottom and right of the print, creating lines 'a' and 'b', respectively. Then, connect point 'B' and '0', creating line 'c', which intersects line 'b' in point '1' (fig.7a). Finally, align the lower right-hand corner of the print (point 'C') with point '1' on the mount-board (fig.7b). The print is now at the optical center of the mount.

This technique is only a good starting point, and not an automatic substitute for accomplished design or personal preferences. If placing the print at the optical center results in an unattractive, narrow border on top or bottom of the print, additional vertical adjustments have to be made. While making these adjustments, the bottom of the print must never lie below line 'd', or the print is in danger of suffering the illusion of sag (see fig.7c). Line 'd' reflects your individual, minimum, vertical print offset. Its location depends on your personal preference and style, but I suggest keeping line 'd' at least 10% above line 'a'.

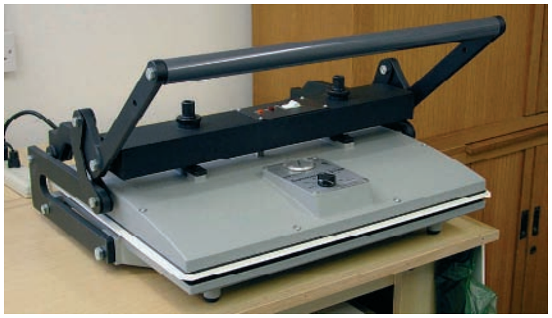
Let us summarize the method of finding an optically pleasing print placement. Locate the optical center (see fig.7a), and place the print at that location (see fig.7b). If this results in the print being too high or too low on the mount, slide it up or down until you reach a more attractive distribution of space, while always maintaining a minimum, vertical print offset (see fig.7c). In most cases, optimum print placement is achieved when the print is horizontally centered and its bottom edge is vertically located between points '1' and '2'.

## Mounting Tools and Recommended Practices

In addition to a clean, comfortable and well-illuminated work space, you need a few special tools and utensils to mount and mat your prints effectively. The most expensive item by far is a dry-mount press (fig.8). It holds mount-board, dry-mount tissue and print in place under pressure, while melting the tissue to form a permanent bond. With a bit of luck, a dry-mount press can be found secondhand, and they usually last a long time, before they might need a heating element or a thermostat replaced. You also need a good mat cutter, which ought to be large enough to cut 32x40-inch sheets in width (fig.9). Make certain that it can cut bevels into 8-ply boards and at least 1/4 inch (6 mm) thick backing board to size.

Continuing down the list of specialty items, we come to the tacking iron (fig.10). This is a miniature iron, obtainable from your mounting supplier, or often for less money, in hobby and craft stores. I prefer the adjustable type with the smooth Teflon finish. They do not get hot enough to melt the dry-mount tissue thoroughly, but they heat it just enough to tack it to the backside of the print and to the mount-board, keeping everything together and in place until the final bond is completed in the dry-mount press. In order for the dry-mount tissue to stick to the print and mount-board, but not the tacking iron, you need a sheet of release paper. This paper has a silicon coating on one side, which inhibits the adhesive from bonding to it. Your mounting supplier sells release paper by the roll, but the backing sheets of printer labels work adequately as a substitute. The last special mounting tool required is a simple burnishing bone (see fig.15f). It is used to give the bevel cuts in the overmat a final touch. They are also available from your mounting supplier.

fig.8 The most expensive mounting tool is a dry-mount press. It holds mount-board, dry-mount tissue and print in place under pressure, while melting the tissue to form a permanent bond.



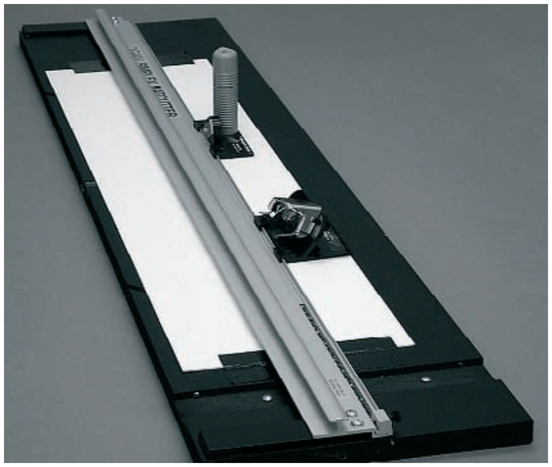


fig.9 A good mat cutter is large enough to cut 32x40-inch sheets in width. It can also cut bevels into 8-ply boards and 1/4 inch thick backing board to size.

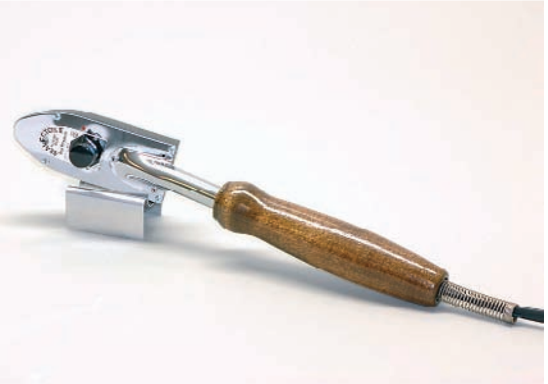


fig.10 A tacking iron is used to keep print, dry-mount tissue and mount-board temporarily aligned, until the final bond is made in the dry-mount press.

The remaining utensils required are minor items, and you probably have some of them already. They include a short and a long stainless-steel ruler to take a few measurements and to have a solid cutting guide; a soft brush to frequently dust things off; a couple of drafting weights to serve as an extra pair of hands; a small but sharp knife with replaceable blades to trim the print and dry-mount tissue precisely; lint-free gloves to avoid fingerprints on the print; a hard and a medium soft pencil to mark dimensions and to sign the artwork; and a calculator and a soft eraser to avoid and correct mistakes.

Physical print placement, with only the aid of a ruler, is certainly possible, but it can be tricky and cumbersome. It often necessitates many, continually decreasing adjustments until the print is precisely in the preferred location on the mount-board. If you plan to mount prints regularly, consider the acquisition of a mounting jig. There are different models available for purchase, but I made mine from a spare baseboard of my, now wall-mounted, enlarger (fig.11). It makes the horizontal alignment of mount-board and print centers effortless and keeps the print horizontal, while trying to find the best vertical location.

Finally, you need a large and rigid surface, free of obstacles, on which to work. For this purpose, I made myself a 3x8-foot table from birch wood. It has a comfortable working height and shelves to store supplies (fig.12). To protect the table-top from cuts, I use a 2x3-foot self-healing cutting-mat (obtainable from craft or fabric stores), or if more space is necessary, I just use a fresh piece of mounting board. The table is large and rigid enough to accommodate the long mat cutter (on the left) and to carry the heavy dry-mount press (on the right).

Another prerequisite for successful mounting is cleanliness. Fingerprints on fine photographs are totally unacceptable, but fortunately, they are also completely avoidable. For that reason, I strongly recommend always wearing lint-free gloves whenever handling, mounting, matting or framing prints.

Unfortunately, there are other gremlins, trying to spoil our print presentation. Always guard against small particles, coming from framing debris, paper trimmings, fabric fibers, hair or dust, just to name a few. If they get under dry-mount tissue or print, they are likely to show through the print surface and create an objectionable 'pimple'. If such particle finds its way between the print surface and the upper plate, or the insertion board, of the dry-mount press, it may leave a visible imprint and unsightly 'dimple' on the print. Pimples are impossible to remove and ruin the already mounted print. Dimples cannot be completely removed, but first swelling the emulsion with a tiny drop of distilled water or alcohol, and then leaving it to dry, can reduce the indentation. Even so, dimples still cause unnecessary labor and needless frustration.

Always have the soft brush handy to frequently dust off all mounting and supporting surfaces to bring an end to pimples. For example, when preparing a print for dry-mounting, put it down, faceup onto a clean piece of mounting board, and dust off the image side. Then, pick the print up, dust off the mounting board and place the print facedown. Now, dust off the backside of the print, before applying the same procedure to the dry-mount tissue. This is an elaborate process,

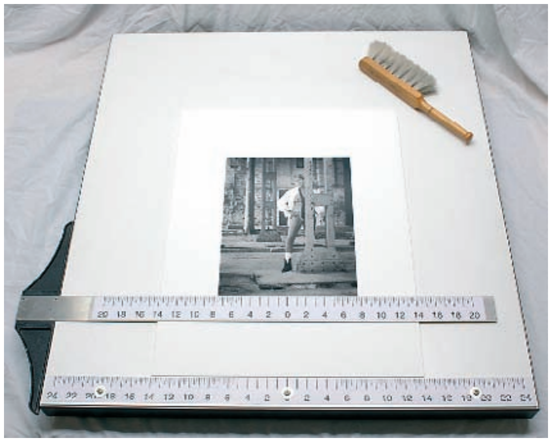


fig.11 If you plan to mount prints regularly, consider the acquisition of a mounting jig. Different models are available for purchase, or one can be made from a spare enlarger baseboard.

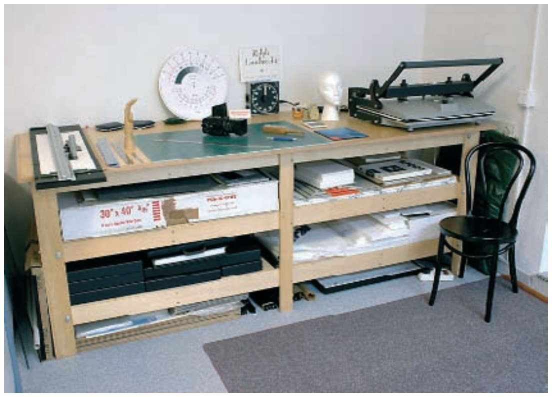


fig.12 A self-made table offers a large and rigid surface to work at a comfortable height, while providing extra shelves to store supplies.

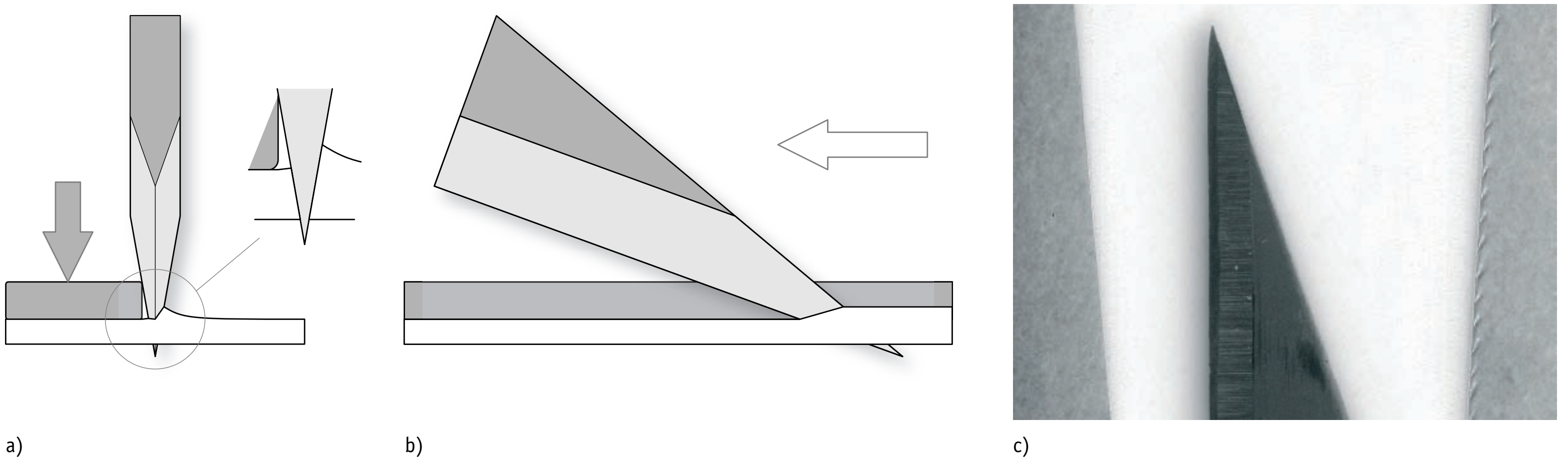


fig.13 During cutting, the wedge-shaped blade forces its way through the paper under a certain angle, pushing the upper paper fibers further aside than the lower fibers (a-b). This different displacement of interwoven fibers causes them to bulge, and occasionally rip, at the paper surface, unless fiber movement is somehow restricted. By sliding the cutting blade alongside a steel ruler, and pushing this ruler firmly down onto the paper during cutting, one side of the paper is constrained, while the other remains free to move. As a result, the side sandwiched between ruler and cutting-mat will have a reasonably smooth and clean edge, whereas the other side will be rough and jagged-looking (c).

but it is the only way to steer clear of pimples. Occasionally, clean the upper plate of the dry-mount press, or replace the insertion board to prevent dimples, and never forget to wear the gloves.

Using exclusively fresh, truly sharp, cutting blades is another requirement to avoid disappointment. Trying to squeeze the last bit of performance out of a blade is definitely false economy. The sensitive cotton fibers of museum board, for example, demand the sharpest blades possible to guarantee a smooth and clean cut. If the blade is even remotely dull, it will rip the fine fibers more than cut them. For simply cutting boards to size, this might be tolerable up to a point. However, for delicate and forever-visible bevels of an overmat, anything less than a flawlessly clean cut is completely unacceptable. A less than perfect overmat must be discarded and replaced, before it gets a chance to spoil the entire print presentation and ruin the photographer's reputation. At today's material prices, the replacement cost for a new overmat is roughly equivalent to the cost of thirty new blades. A timely blade replacement proves to be a worthwhile investment!

When trimming prints, the cleanest cut is attained using a steel straight-edge or ruler, and a scalpel with a fresh, very sharp blade. However, handle these tools with extreme care. A sharp scalpel respects the toughness of steel as a guide, but it does not differentiate between paper and fingers. I strongly suggest using a ruler with a finger guard. Always keep the ruler on the print and not on the cut-offs. It is inherent to the cutting process that the material is divided, but unlike sawing, no material is lost or removed; it is just displaced. However, the displacement is not consistent. As the wedge-shaped blade forces its way through the paper under a certain angle, it always pushes the upper paper fibers further aside than the lower fibers (fig.13a-b). This different displacement of interwoven fibers causes them to bulge, and occasionally rip, at the paper surface, unless fiber movement is somehow restricted. By sliding the cutting blade alongside a steel ruler, and pushing this ruler firmly down onto the paper during cutting, one side of the paper is constrained, while the other remains free to move. As a result, the side sandwiched between ruler and cutting-mat will have a reasonably smooth and clean edge, whereas the other side will be rough and jagged-looking (fig.13c). Consequently, it makes for cleaner print edges to always trim print and dry-mount tissue with the ruler placed on the print and not on the cut-offs. Be sure that the steel ruler has no sharp edges or burrs, which could scratch the sensitive print surface.

## Mounting and Matting (Step by Step)

### Dry-Mounting

Start by preparing a clean and well-lit work area, and get all tools and materials ready to go. Turn-on the tacking iron and the dry-mount press, select the appropriate temperature for the dry-mount tissue used, and leave them to warm up. Meanwhile, cut a mount-board, matting-board and a backboard to size, and put them aside for now. Do the same for the dry-mount tissue, unless you have the pre-cut sheets (see fig.14a). The tissue dimensions should be slightly larger than the untrimmed print (1.5 mm or 1/16 inch, on each side), to make double sure that the adhesive will reach the entire print periphery, even if it is slightly misaligned in the next step.

Cover the work surface with some spare, but clean, mounting board to have a smooth surface to work on. Dust-off work surface, print and dry-mount tissue well. Put the print facedown, cover it with the dry-mount tissue, and place a piece of release paper on top. Use one hand or a drafting weight to hold it all in place, and press the heated tacking iron onto the release paper (see fig.14b). Make certain that the flat surface of the iron rests evenly on the paper. Without pressing it down too hard, and while keeping the tacking iron in small circular motion, apply the heat for about 20 seconds, until the dry-mount tissue sticks to the print. Repeat in a second location, but stay on the same half of the print. We need the other half to be unattached, when we tack it to the mount-board later.

Turn the print and dry-mount tissue carefully around, and trim the edges, as appropriate for the print composition (see fig.14c). I suggest trimming off at least a millimeter or two, regardless of any artistic considerations. This way, all residual chemicals, which penetrated the print edges and were not washed out completely during print processing, are removed. After trimming, print and dry-mount tissue are precisely the same dimensions and are perfectly aligned to each other (see fig.14d).

Take the two pieces of already sized mount-board and critically inspect them front and back. Mounting board often has unavoidable minor flaws or imperfections. As tiny as some of them are, they will certainly catch the observer's eye and create unwanted distractions. It is almost impossible to remove these flaws from the fibers, without leaving obvious telltale signs of repair work. It is far easier to leave them alone, but relegate minor imperfections to the back of the boards. If you find them on both sides of a board, hiding them becomes more difficult, although you may still have the opportunity to successfully conceal them with the print or the overmat, or better yet, you may be fortunate enough to lose them to the window cut-out of the overmat. Inspecting both boards prior to use will also help you decide which of the two pieces is more appropriately used as a mount-board and which as an overmat. Nevertheless, every once in a while, it seems impossible to lose or hide all board flaws. In that case, replace it with a fresh piece, and save the rejected board for a future application, hoping for the next print or overmat to cover or lose all imperfections.

Select which board is to be used as the mount-board, and save the other as the mat-board. Depending on the storage conditions of the mounting board used, you may elect to slip the mount-board into the dry-mount press for two minutes to dry it out before mounting the print. High initial moisture content of the mount-board can cause adhesion problems with the dry-mount tissue or may cause the board to bend or warp after bonding. Leave the board, for two more minutes, to dry and cool down.

Take the dried mount-board and select the most suitable mount orientation, considering print orientation and presentation style. Use two drafting weights, as an extra pair of hands, to keep the mount-board from moving around (see fig.14e). Then, use a jig, or a small ruler, to determine the optimum print placement on the board. The print should be centered left to right, and the bottom border should be larger than the top (see fig.14f-g). Start with the optical center, and work your way up or down from there, if needed.

Set another drafting weight on the print to secure its location, but be sure to put it on the side that is already attached to the dry-mount tissue. On the other side, slip the release paper between the print and the tissue. Now, place the tacking iron below the print but on top of the release paper, and tack the dry-mount tissue to the mount-board at one or, better, two places (see fig.14h). Remove the release paper. The print and the dry-mount tissue are now attached to the mount-board at the desired location, while still perfectly aligned to each other (see fig.14i), but the bond is still weak. Handle the assembly carefully, and do not hold it upright or the print might tear off.

It is important to choose an appropriate dry-mount operating temperature. If the temperature is too low, the bond is weak, and the print will delaminate at the corners and edges. If the temperature is too high, the print will get damaged, or if high enough, the adhesive will form bubbles and ruin the mount. The actual press temperature can be tested with a small thermometer, fitted into the press between two sheets of mounting board. FB prints can be exposed to fairly fig.14 a) Cover the work surface with some spare mounting board, to have a smooth surface to work on. Get the print and dry-mount tissue, and dust-off everything well.

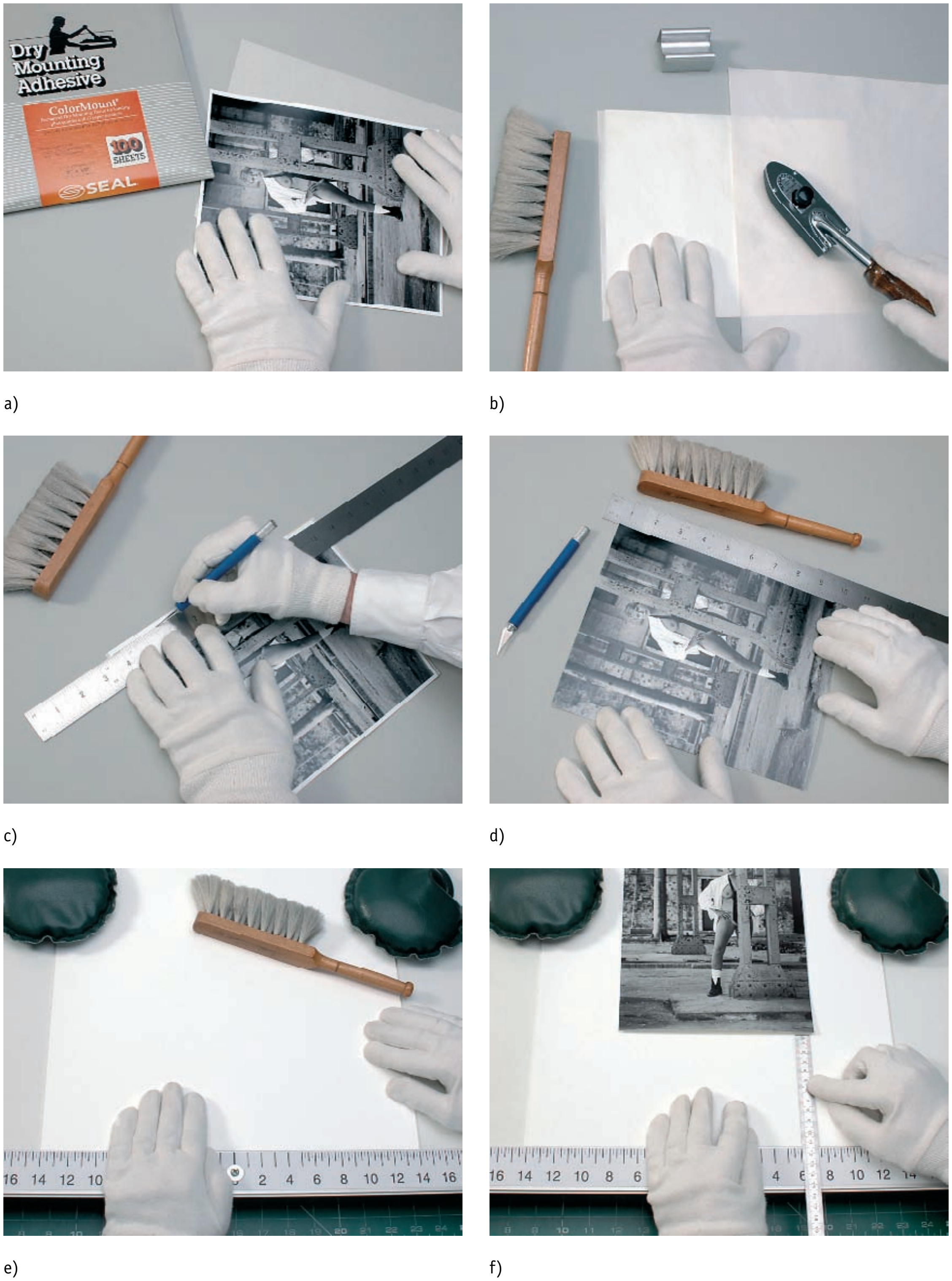
b) Put the print facedown, cover it with the dry-mount tissue, and place the release paper on top. Put the heated tacking iron down flat, so it rests evenly on the paper. Apply the heat for about 20 seconds, until the dry-mount tissue sticks to the print. Repeat in a second location.

c) Turn the print and dry-mount tissue around, and trim the edges, as appropriate for the print composition, but trim off at least a millimeter. This way, all residual chemicals, which were not washed out completely during print processing, are removed.

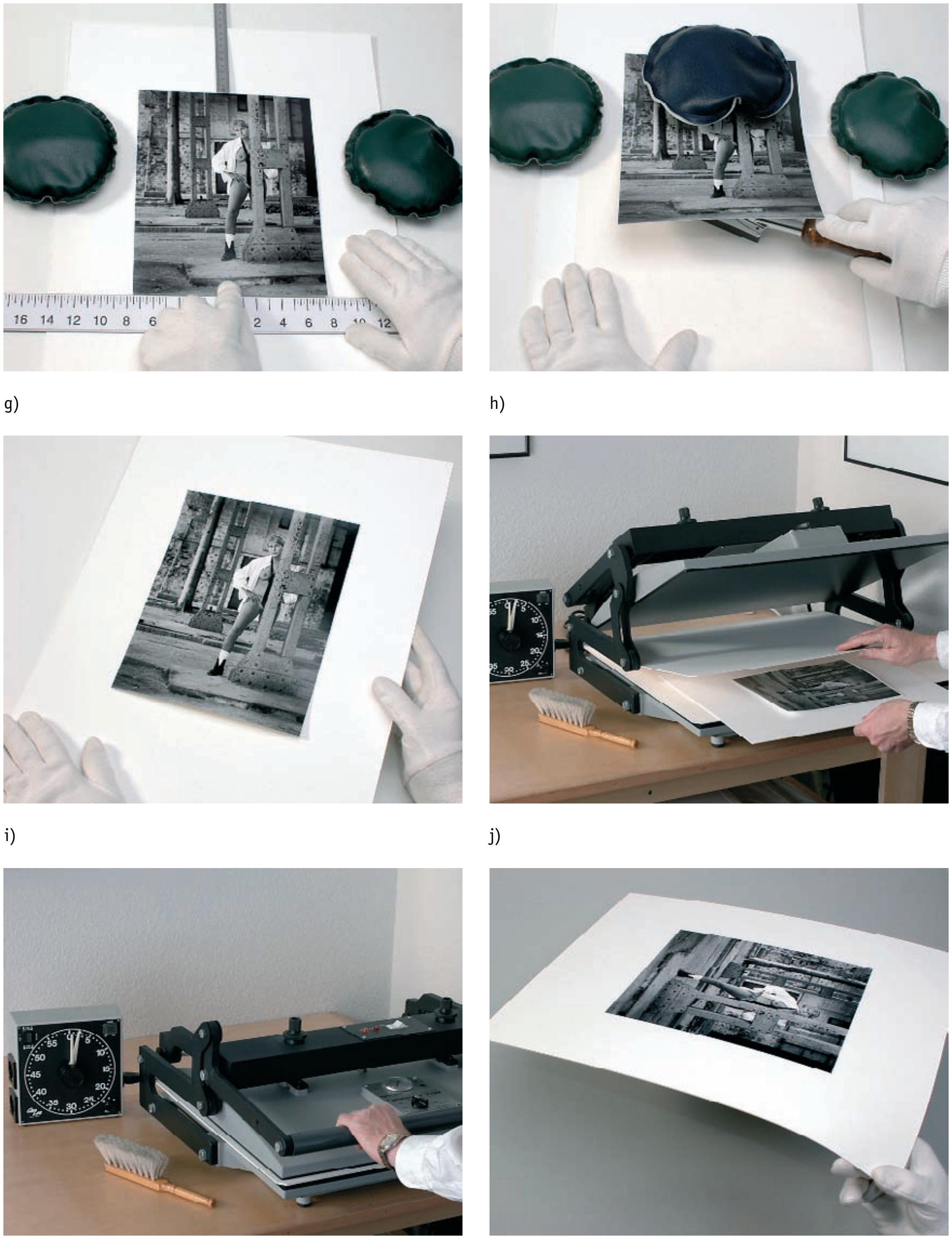
d) After trimming, print and dry-mount tissue are precisely the same dimensions and are perfectly aligned to each other.

e) Take the mount-board and select the most suitable mount orientation to present the image. Generally, the presentation mirrors the print: vertical presentation for vertical prints and horizontal presentation for horizontal prints.

f) Use drafting weights as an extra pair of hands to keep the mount-board from moving around. Then, use a jig, or a small ruler, to determine the optimum print placement on the board.



a) b) c) d) e) f)



g)

h)

i)

j)

k)

l)

fig.14 g) The print should be centered left to right, and the bottom border should be larger than the top, while not letting the top border to become smaller than the sides.

h) Set a drafting weight on the print to secure its location, and slip the release paper between the print and the tissue. Now, place the tacking iron below the print but on top of the release paper, and tack the dry-mount tissue to the mount-board.

i) Remove the release paper. The print and the dry-mount tissue are now attached to the mount-board at the desired location, while still perfectly aligned to each other, but the bond is still weak. Handle the assembly carefully, and do not hold it upright or the print might tear off.

j) Insert the print assembly between two sheets of clean mounting board and close the dry-mount press.

k) Keep the press closed for up to two minutes for RC prints and up to three minutes for FB prints, but follow manufacturer's instructions for operating temperatures and times.

l) Take the mounted print from the press, and place it under glass for five to ten minutes. After it has completely cooled, check the print adhesion, by holding the mount-board at each edge without permanently bending it. Inspect all print corners to make sure that print and tissue are not delaminating from the mount-board.

high operating temperatures (up to 225°F or 105°C). RC prints require lower temperatures (not more than 200°F or 95°C), otherwise the plastic layers on the paper will melt and ruin the print. Therefore, RC papers call for special dry-mount tissue, which melts at a lower temperature than the plastic on the paper does. I prefer porous dry-mount tissue with a low minimum operating temperature (175°F or 80°C), which is, consequently, suitable for both FB and RC prints, as well as other sensitive materials.

Heat distribution in the dry-mount press must be even, without hot spots. I have two sheets of mounting board in my dry-mount press. The top sheet distributes the heat from the upper plate more evenly and reduces dimpling of the print surface. The bottom sheet keeps the lower foam pad clean. Insert the print assembly between the two sheets and close the dry-mount press (see fig.14j-k). Keep it closed for up to two minutes for RC prints and up to three minutes for FB prints, but follow the instructions of the dry-mount press and tissue manufacturer for appropriate operating temperatures and times.

Take the print from the dry-mount press, and quickly place it under a thick sheet of glass for five to ten minutes, which allows the molten adhesive to cool and solidify, without curling the print or warping the mount-board. Some printers recommend the use of an aluminum sheet instead, for improved heat dissipation, but for me glass works fine, is perfectly flat and inexpensive. After the print has completely cooled, you might want to check the print adhesion. To do so, hold the mount-board at each edge (see fig.14l) without permanently bending it. Inspect all print corners to make sure that print and tissue are not delaminating from each other or from the mount-board. If they are, simply return them to the press for more time, possibly at a slightly higher temperature.

## Matting

The only difference when cutting an overmat for a dry-mounted print or a corner-mounted print is the size of the window opening. When matting a dry-mounted print, as illustrated in fig.15, the window opening may be large enough to expose the entire print and some of the mount-board around it. The window opening for a corner-mounted print, however, needs to be small enough to secure and cover the print periphery.

Get the mat-board and inspect it for imperfections again, making sure that any imperfections either are on the backside or will be removed with the window opening. It is easier to mark the window cutting if a relatively large work surface is available, so the mount and mat-board may be positioned next to each other.

Put mount and mat-board down so that the print and the backside of the mat-board are facing you. With the help of a ruler, measure the distance from the print border to the edge of the mount-board on all four sides. Deduct 5/8 inch (15 mm) from the left, top and right measurements to derive the desired dimensions for the overmat window (see fig.15a). Draw soft, thin lines from edge to edge onto the mat-board at the respective locations (see fig.15b). Do the same for the bottom of the mat-board, but deduct 3/4 to 1 inch (20 to 25 mm) to gain more room below the print. You will need this extra space to identify the mounted print with your signature and an edition number. Mark the top-right corner of the mat-board as 'top-left' (see fig.15c). Remember, the mat-board is still lying facedown, so 'left' and 'right' are opposite! This will help to identify and maintain the correct mat-board orientation on the mount-board after cutting the window opening.

Refer to the instructions that came with your mat cutter for the correct procedure on how to cut the window opening into the mat-board, as this depends somewhat on your specific equipment (see fig.15d). However, some advice for efficient use of a bevel-cutter seems universal. Cut the short edges first, so the remaining edges give maximum support to the window cut-off. Over-cut all edges by about one or two millimeters, ensuring that the corners are cut all the way through. A window cut-off hanging from one corner can rip the fibers and ruin the entire mat-board. The cuts along all four edges must completely separate the window cut-off from the overmat.

Matching the 'top-left' marking on the backside of the overmat to the print's top-left, place the overmat on the mount-board and verify that the window opening has been cut correctly (see fig.15e). The freshly cut bevels always have a slight burr on the show-surface of the overmat, no matter how sharp the blade is. Use the burnishing bone to smooth all four edges and the corners of the bevel (see fig.15f). To do this, run the bone across the bevels, with only light pressure applied. Using one of the bone's edges, get deep into the bevel corners, and use the bone tip to smooth out the bevel over-cuts on the show-surface. A burnishing bone improves bevel appearance significantly.

Place mount-board and overmat next to each other, like two facing pages of an opened book, with the overmat still lying face-down. With the aid of a thin steel ruler, wedged between the two boards, create a thin, consistent gap between the two boards to provide room for a taped hinge (see fig.15g). Secure the position of the boards with two drafting weights. At a safe distance from the mounting area, get a clean, dripping-wet washcloth, fold it and put it into a 5x7-inch processing tray, large plate or dish. The set-up shown in fig.15h is purely for illustration purposes. I cannot recommend allowing water so close to your artwork, since it creates a significant risk of getting spills or drips onto the print.

Cut two pieces of the gummed, acid-free cloth tape of generous length. Four to six inches (100 to 150 mm) is about right. These will be used to create the hinge between mount-board and overmat. Take one of the two pieces of tape, thoroughly wet the gummed adhesive by pressing the tape onto the washcloth, and gently press the tape onto one half of the boards, trying to get the tape evenly onto both boards (see fig.15h). Repeat on the other half of the boards with the second piece of tape, and remove the drafting weights (see fig.15j). Before the water-soluble adhesive has a chance to dry, making slight adjustments impossible, close the assembly, and make sure the overmat and the mount-board are aligned correctly. If not, there is still time to tweak the arrangement (see fig.15j). After you are completely satisfied with the alignment, use the drafting weights again to keep everything in place for a minute or two, while the adhesive dries.

To finish dry-mounting and matting a print, make the artwork identifiable by adding an edition number on the left (see fig.15k), and by signing and dating the mount-board on the right (see fig.15l), just below the print. The dry-mounted and matted print is now presentable and ready for framing.

## Corner-Mounting

Fig.16 illustrates corner-mounting, which is an alternative to dry-mounting. Both processes utilize the same tools and materials with the exception that a corner-mounted print is held, as the name implies, at the corners by plastic or paper pockets. The corner pockets can be purchased or self-made from acid-free paper. Since most purchased pockets, made of plastic (polypropylene), are backed with a self-adhesive of unknown origin, I prefer to make the corners myself from acid-free cotton paper.

Cut a 1x2-inch (25x50-mm) piece of acid-free paper, and fold it from the center of one of the long sides to both opposite corners, creating one large and two small triangles (see fig.16a, step 1-4). Unfold the paper, and 'hollow' out the large triangle, leaving only a small border of about 1/8 inch (see fig.16a, step 5-6). After turning the paper around, the newly made paper pocket is slipped over the print corner (see fig.16b).

Make a pocket for each corner, slip them over the print, place the print on the mount-board and secure it with a drafting weight (see fig.16c). Cut an overmat, with a window opening small enough that the corner pockets and the print borders are hidden. Place the overmat on top of the print, and check the window opening for size (see fig.16d). Hinge-mount the overmat, and adjust final print alignment if necessary (see fig.16e). Finally, cut four pieces of 2-inch (50 mm) long, gummed, acid-free paper or cloth tape, and firmly press the tape onto the corner pockets, avoiding contact between the tape and the print (see fig.16f).

The print is now corner-mounted and ready for framing. Do not expect the print to be as flat as its dry-mounted counterpart would be. This is a trade-off for the flexibility of being able to remove the print from its mount with ease.

## Print Identification

The final touch to a competently mounted and matted print is the full identification and personalization of the artwork. This not only provides future observers and prospective buyers with providence of the print, but it also increases the print's potential value as a collector's item and demonstrates the artist's full commitment to the work accomplished. To follow the guidelines of not distracting from the image itself, print identification must be clear, but modest.

I prefer to have the print edition number, the date and my signature (but not the image title) readily available while looking at the image. Therefore, this information is entered just below the print onto the mount-board, where it is still exposed by the window in the overmat (see fig.15k-l). I use a medium soft and almost dull pencil, making clearly legible but delicate fig.15 a) Put mount and mat-board down so that the print and the backside of the mat-board are facing you. Measure the print borders and deduct the desired clearances to derive the dimensions for the overmat window. Leave more room below the print to have some extra space for signature and edition number.

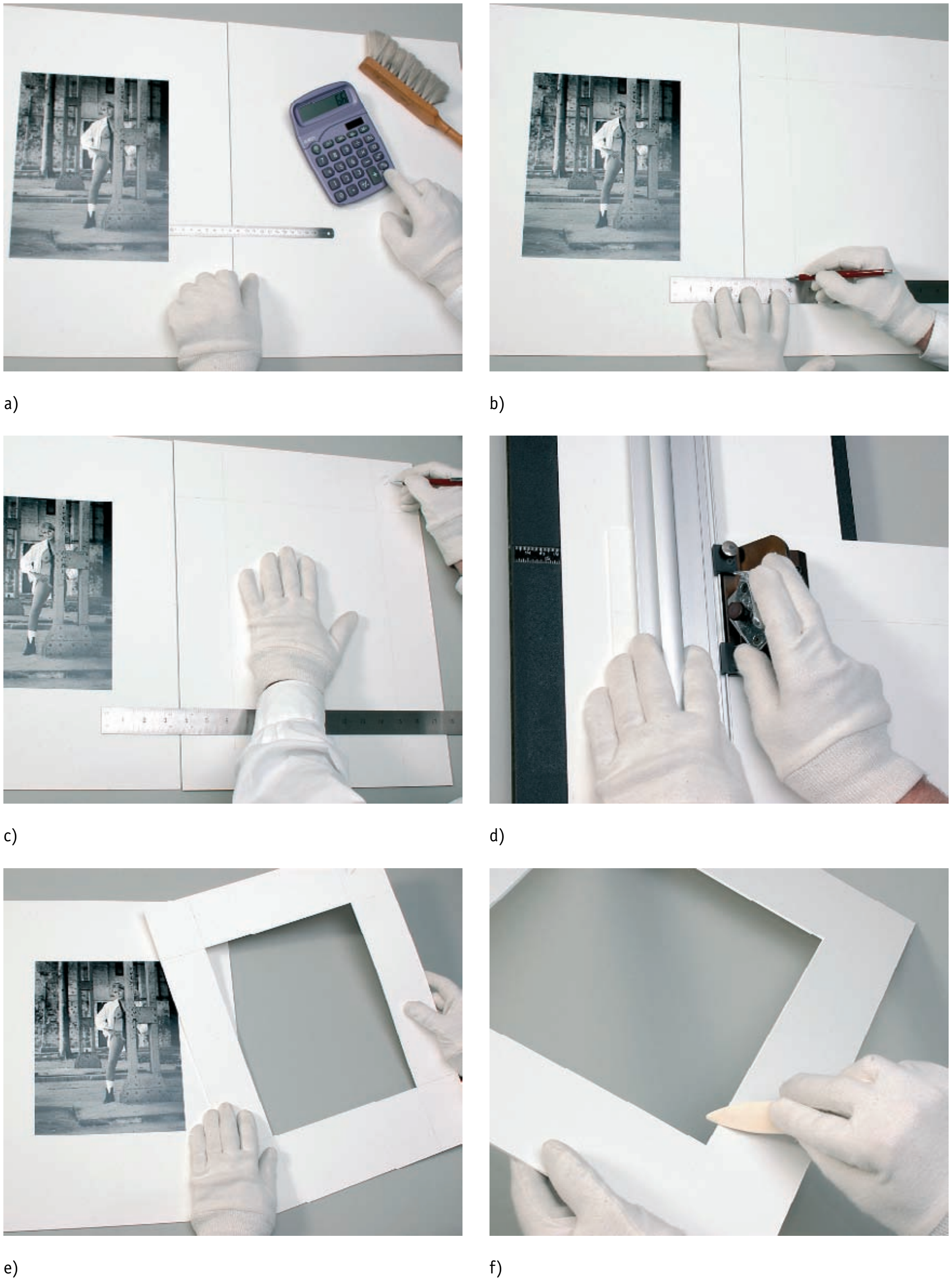
b) Draw thin lines onto the mat-board at the respective locations.

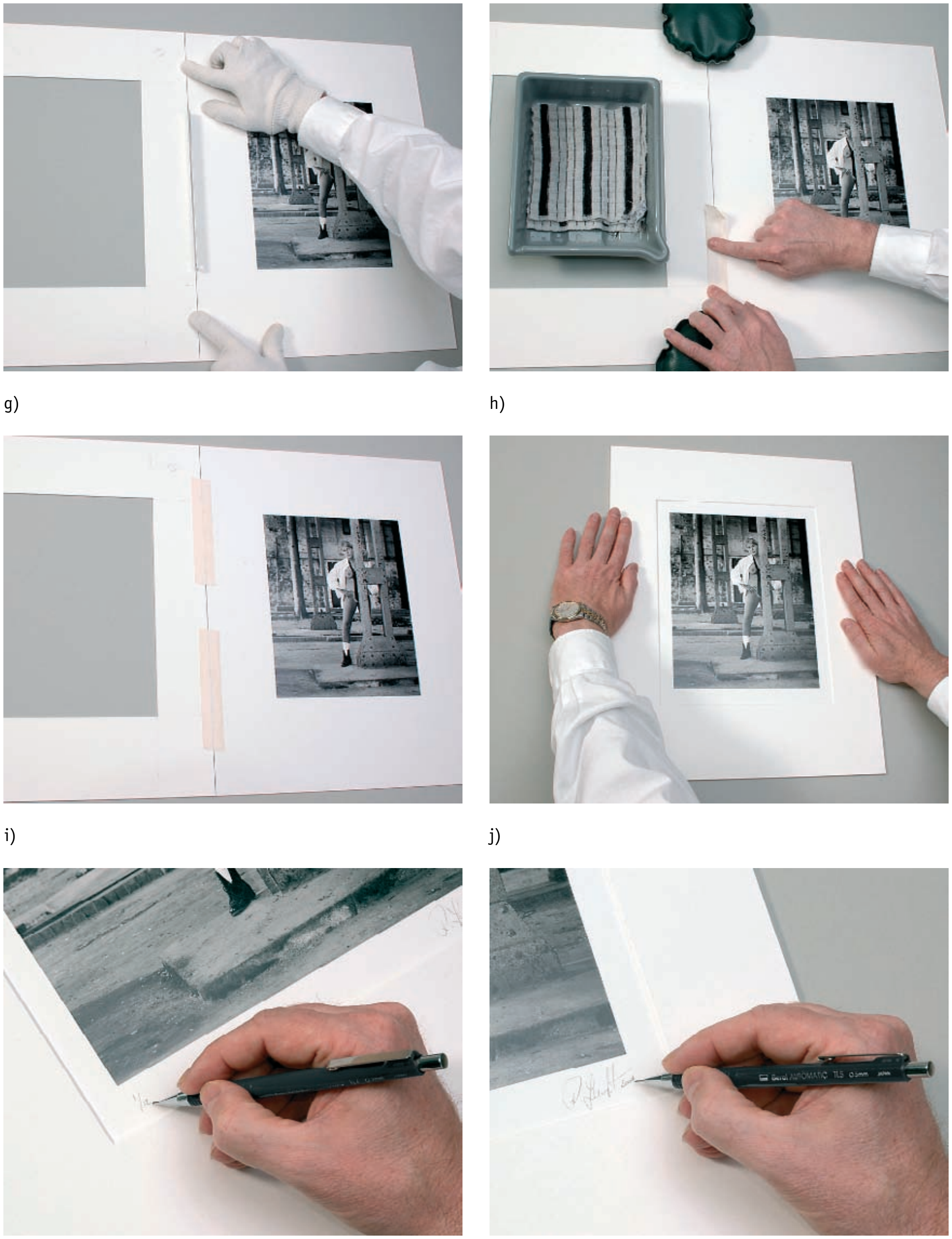
c) Mark the top-right corner of the mat-board as 'top-left'. Remember, the mat-board is still lying facedown! This will help to identify and maintain its correct orientation on the mount-board after cutting the window opening.

d) Refer to the instructions that came with your mat cutter, for the correct procedure on how to cut the window opening into the mat-board.

e) Matching the 'top-left' marking on the backside of the overmat to the print's top-left, place the overmat on the mount-board and verify that the window opening has been cut correctly.

f) Use the burnishing bone to smooth all four edges and the corners of the bevel. Using one of the bone's edges, get deep into the bevel corners, and use the bone tip to smooth out the bevel over-cuts on the show-surface.


a) b) c) d) e) f)



g) h) i) j) k) l)

fig.15 g) Place mount-board and overmat next to each other, with the overmat still lying facedown. With the aid of a thin steel ruler, wedged between the two boards, create a consistent gap between the two boards.

h) Secure the position of the boards with two drafting weights. Cut two pieces of gummed tape, four to six inches in length. Take one, wet the adhesive, and gently press the tape onto one half of the boards, trying to get the tape evenly onto both boards.

i) Repeat on the other half of the boards with the second piece of tape, and remove the drafting weights.

j) Before the adhesive has a change to dry, close the assembly, and make sure the overmat and the mount-board are aligned correctly. If not, there is still time to tweak the arrangement. Again, use the drafting weights to keep the boards aligned, and let the adhesive dry.

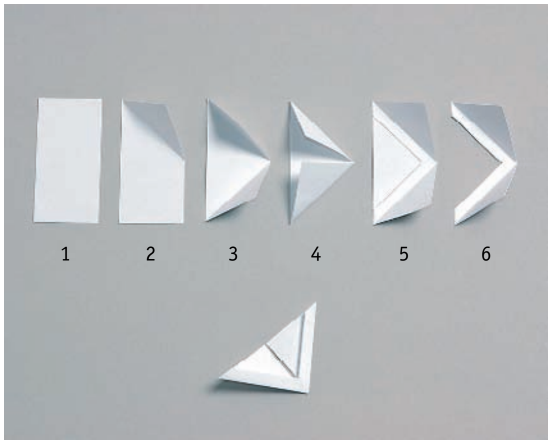
k) To finish dry-mounting and matting a print, make the artwork identifiable by adding an edition number below the print on the left.

l) Then, sign and date the mount-board on the right.

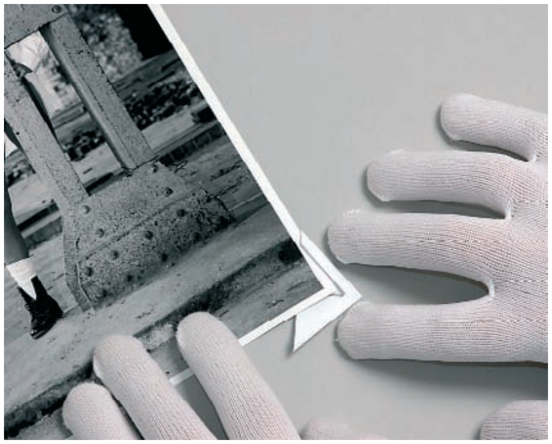
The mounted and matted print is now presentable and ready for framing.

fig.16 a) Cut a 1x2-inch piece of paper, and fold it from the center of one of the long sides to both opposite corners, creating one large and two small triangles (step 1-4). Unfold the paper, and 'hollow' out the large triangle, leaving only a small border of about 1/8 inch (step 5-6).

b) Slip the newly made paper pocket over the print corner.



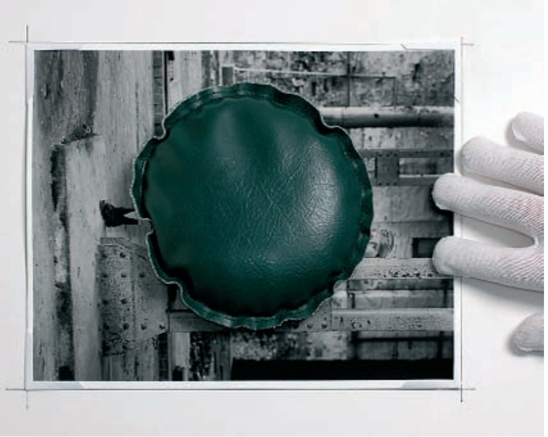
a)



b)

c) Make a pocket for each corner, slip them over the print, place the print on the mount-board and secure it with a drafting weight.

d) Cut an overmat, with a window opening small enough that the corner pockets and the print borders are hidden. Place the overmat on top of the print, and check the window opening for size.

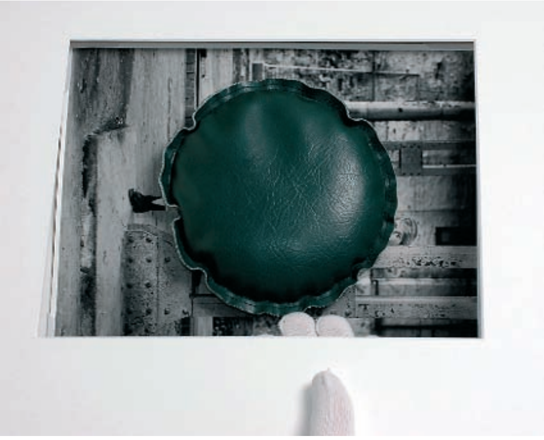


c)

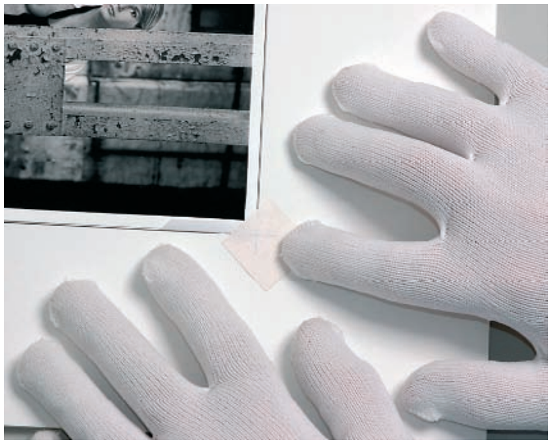
d)

e) Hinge-mount the overmat, and adjust final print alignment if necessary.

f) Cut four pieces of 2-inch long, gummed tape. Firmly press the tape onto the corner pockets, avoiding contact between the tape and the print.



e)



f)

The print is now corner-mounted and ready for framing.

entries. A freshly sharpened or hard pencil will mar the surface and disrupts the smooth flow of writing. A pencil too soft, on the other hand, will make the writing far too dominant, demanding more attention than this secondary information deserves.

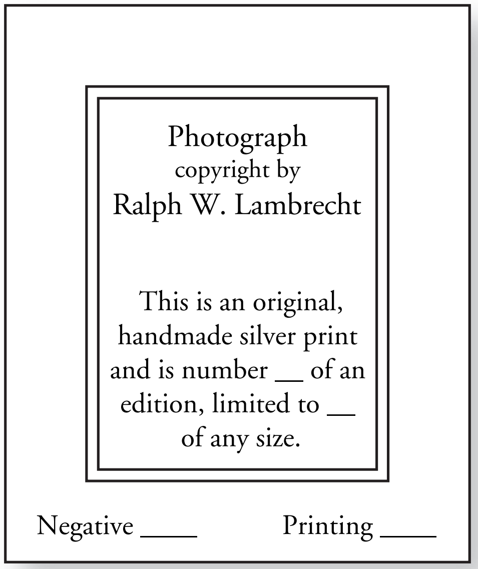
It is clearly up to the artist whether to prepare limited-edition prints or to make an unlimited amount of copies. In the past, I limited my fine-art print editions to twelve copies of any size, after which I made no further prints from that negative. Other typical edition limits are 50, 100, or optimistic photographers may choose 250, 500 or even more. If you are uncomfortable with the potential confinement and the inherent commitment of limited editions, there are alternatives. First, you can just number your prints, starting with '#1', instead of '1/250', or you can prepare print editions like the publishing industry does for books. You will see more on this in the chapter 'What Size is the Edition'.

Next to the signature, in very small print, I routinely add the year the image was taken. Dating the image is often considered necessary to create a meaningful association with a certain era or period, thereby putting the visual information into perspective and making the print more consequential.

Any additional information may be helpful but does not belong on the presentation side of the mounted print. A custom-made rubber stamp (fig.17), which contains the photographer's full name, a copyright and quality statement, room for the date the image was taken and the print was made, as well as space for the print number and the edition, is a good way to record additional information. Stamp the backside of the mount-board and the backboard with acid-free ink, and complete the missing information using an acid-free pen (not a pencil) on both. Now, add the image title somewhere near the stamp.

I keep the image title on the back, rather than on the front of the print. An observer's interpretation of an image is always filtered by personal experiences and current emotions. Therefore, an image is likely to provoke different responses in different people. By presenting the image title on the print, these individual responses are muted, because this title reflects the photographer's image intent and is influenced by the photographer's experiences and emotions. An untitled image is far more likely to provoke a genuine emotion and response in the viewer.

fig.17 A custom-made rubber stamp, which contains the photographer's full name, a copyright and quality statement, room for the date the image was taken and the print was made, as well as space for the print number and the edition, is a good way to record additional information. Stamp the backside of the mount-board and the backboard, and complete the missing information using an acid-free pen.

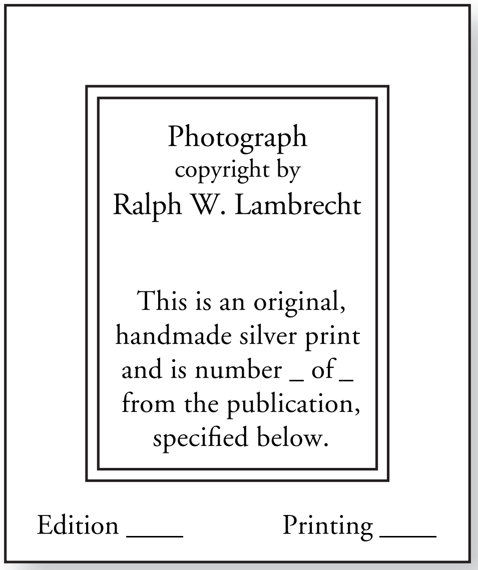


Photograph
copyright by
Ralph W. Lambrecht

This is an original,
handmade silver print
and is number __ of an
edition, limited to __
of any size.

Negative ____ Printing ____

fig.17a This is my old rubber stamp for when I limited my fine-art print editions to twelve copies of any size, after which I made no further prints from that negative.



Photograph
copyright by
Ralph W. Lambrecht

This is an original,
handmade silver print
and is number _ of _
from the publication,
specified below.

Edition ____ Printing ____

fig.17b This is my new rubber stamp, after switching from 'limited printing' to 'true editioning'. During each printing session, I usually make 1-4 prints. If I reprint on another day, it's the next printing session. If I change the printing style for the image, it's a new edition. This allows for an unlimited number of prints and still defines each print precisely for collectors and galleries.

# Print Spotting

## Closing in on perfection with a bit of cleanliness

Few freshly made prints are completely free of visual defects. Unavoidable dust and tiny scratches on the negative, plus the occasional emulsion damage and fingerprint, create unwanted spots, lines and other blemishes on the print. These imperfections must be concealed, because they spoil a clean presentation and distract from the image. Print spotting is the process in which unwanted spots are disguised by adjusting their tonality to match the surrounding tones.

Print spotting is not just cosmetic. Its main function is to remove disturbing visual noise, which gets in the way of print enjoyment and lessens its impact. There usually is a remarkable difference between unspotted and carefully spotted prints, especially when considering how small the alterations often are (fig.1). This makes spotting a highly effective and rewarding task, but it can also be a labor-intensive, time-consuming and sometimes frustrating task, particularly when

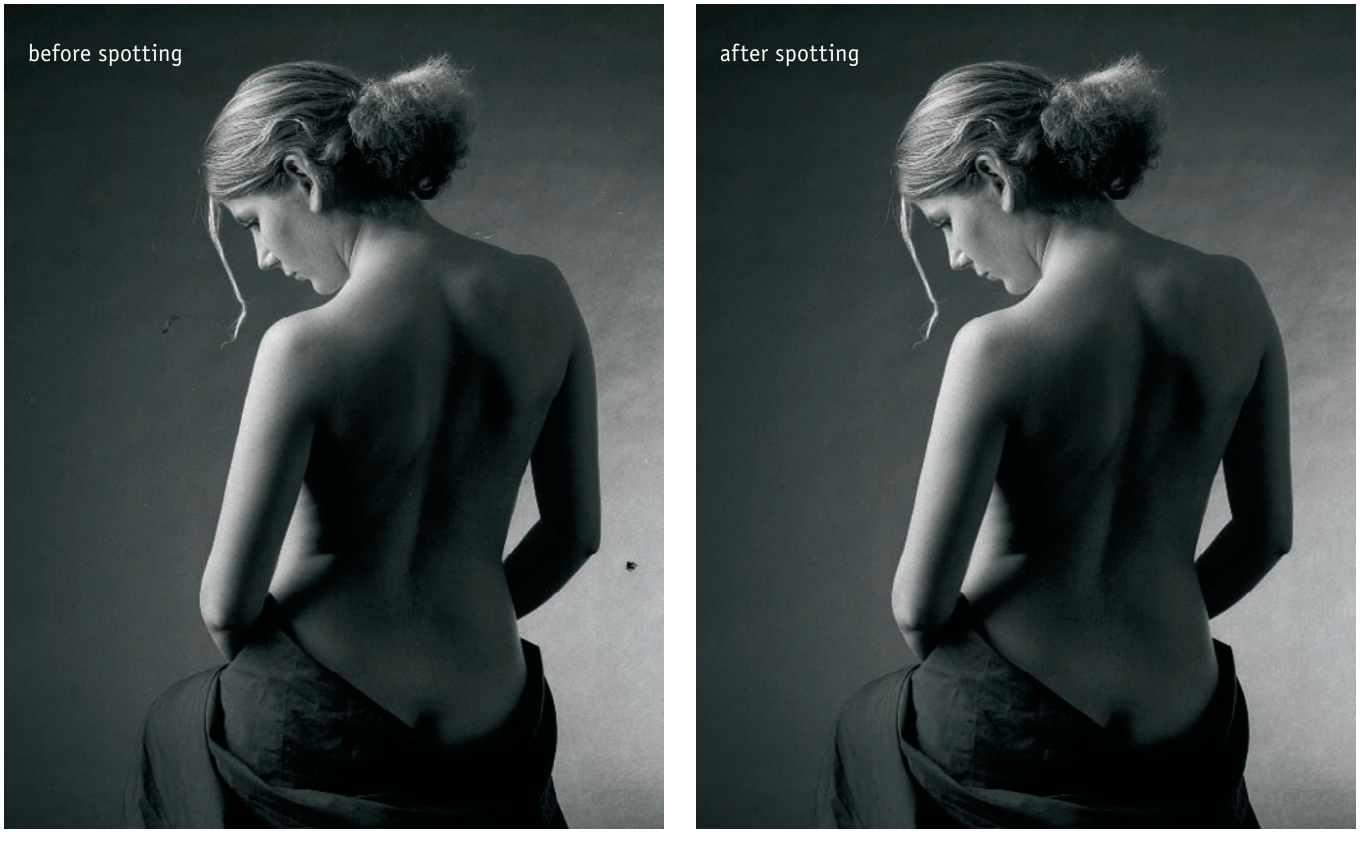


fig.1 There is usually a remarkable difference between unspotted and carefully spotted prints, especially when considering how minute the alterations often are. Print spotting removes disturbing visual defects, which disturb the print enjoyment and lessen its visual impact.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50009-0

it does not work as well as we had hoped. As always, prevention is better than repair, and consequently, it is best to eliminate the need for spotting as much as possible. The less spotting your prints require, the better off you are. The root cause for print blemishes is dirt and dust. To minimize the need for spotting, keep your negatives clean and handle them with care to prevent scratches. Make sure your entire camera equipment and darkroom are as tidy and dust-free as possible. Remove dust from work surfaces, cameras and film holders on a regular basis. Gently remove all loose dust from the negative and the enlarger's negative holder with compressed air or an anti-static brush before printing them. Carelessly stored, ill-treated or much-printed negatives may benefit from a gentle wash prior to using them again.

## White Spots and Black Spots

There are two types of print imperfections that require spotting, white spots and black spots. Most blemishes are much lighter than their surroundings. Most are caused by small dust particles stuck to the negative or to the glass of the negative carrier. They are highly distracting but easy to remove. Others are telltale signs of small fibers and hair, leaving thin, bright trails on the print. They need a bit more patience and practice to disguise. Dark spots are typically caused by dust on the film during in-camera exposure or by damage to the negative emulsion. Some literature recommends etching the print surface to remove blemishes that are darker than their surroundings. However, etching requires scratching and irrevocably damaging the print's surface. I will demonstrate how this is completely avoidable when print spotting is combined with other retouching techniques.

## Spotting Equipment and Materials

Print spotting is accomplished by using a small brush and repeatedly applying a darker dye to a lighter spot, line or blemish, until its shade closely matches the surrounding tones and blends into the rest of the print. The goal is not to eliminate the imperfection altogether, but to move it from attention-grabbing boldness to inconspicuous obscurity.

The ideal work area for spotting is dry, uncluttered and dust-free. It also provides bright and even lighting, has a good-size sturdy table and comfortable seating. Typical spotting tools include a large magnifying glass or extra-strong reading glasses, a set of very small, fine-tip, high-quality brushes, a pair of clean, lint-free nylon or cotton gloves, some blotting paper or a paper towel, a few spare pieces of mountboard and a saucer or porcelain palette to mix and dilute the spotting dye (fig.2). Make sure to also have a cup of distilled water and an eyedropper handy.

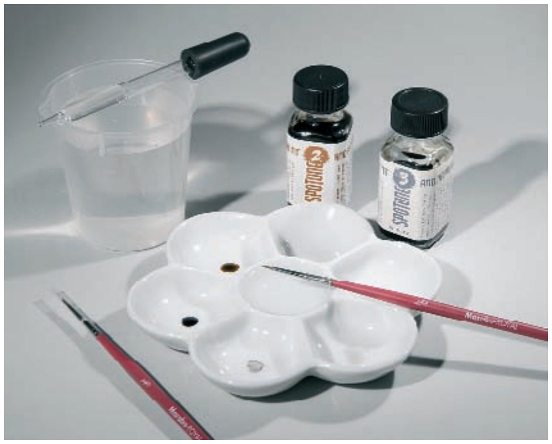


fig.2 Typical spotting tools include a large magnifying glass, a set of high-quality brushes, some blotting paper, a porcelain palette to mix and dilute the spotting dye, a cup of distilled water and an eyedropper.

### Spotting Brushes

Your set of fine-tip brushes needs to include only the smallest sizes. Start with a #000 (3/0) brush for larger spots, and attack smaller imperfections with a #00000 (5/0) brush. Be sure to buy only the best, evenly shaped, animal-hair brushes available, or your spotting efforts will be more tedious and frustrating than necessary. A high-quality brush features enough bristles to readily absorb the spotting fluid, while still forming a fine-point tip and allowing full control over the fluid amount released by varying the pressure applied to the tip of the brush.

### Spotting Dyes

The best-suited materials for spotting monochrome prints are light-stable, black dyes and pigments, which are suspended in a quick-drying, water-soluble solution. This way, the spotting dye can be diluted with water to create any shade of gray from a barely visible light tone to a deep dark black. Once applied to the print, the dye is absorbed by the paper emulsion and penetrates into the fibers without appreciably changing the surface texture or its reflectance.

One prominent brand of spotting dye was Spotone, made by Retouch Methods, Inc., but unfortunately, the company no longer exists. They produced dyes of various colors, and by mixing them, one could match any print color, regardless of paper brand or toner used (see fig.3a). You may still be able to acquire a bottle of Spotone through a secondhand source, in which case, you will be glad to know that a single bottle will most likely last you a lifetime. The most useful color in the Spotone line of shades is #3 (neutral-black base), which has a colorless, black tone. By mixing #3 with small amounts of #2 (selenium brown), the tonality can be changed to closely match the tones of a typical sulfide or selenium-toned print. Further color matching is

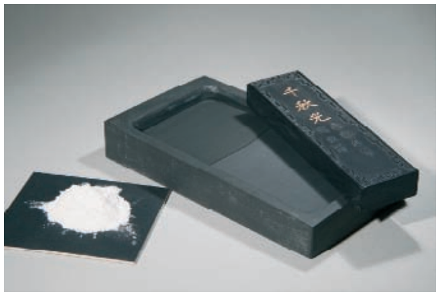
a)

fig.3a Spotone is, unfortunately, no longer available, but it is still possible to acquire this once-prominent brand of spotting dye through secondhand sources. By mixing various colors, any print tone, regardless of paper brand or toner used, can be matched.

Marshall's
SPOT-ALL
KIT 3 BT

b)

fig.3b Marshall's Spot-All dyes are still available, very similar to Spotone and work on the same principle. The dye is readily absorbed by the emulsion and paper fibers without appreciably changing the surface texture or its reflectance.



c)

fig.3c Going back to the very roots of ink making, grind some solid India or China ink, mix it with an equal amount of gum arabic and dissolve together in distilled water. Gum arabic promotes print adhesion and controls the gloss level of the spotting dye.

PERFECT
OPAQUE
LIQUID

d)

fig.3d Special opaque liquids are used to cover up small holes in the negative emulsion. This way, they convert hard to remove, dark print spots into bright white spots, which are much easier to spot and blend into their surroundings.

possible with #0 (olive black) and #1 (blue-black), but most spotting needs are adequately covered with Spotone #3 and #2. Marshall's manufacture an alternative line of spotting dyes, called Spot-All (fig.3b). It is available in neutral-black, selenium-brown and blue-black. As of this writing, they are still available and just as easy to mix and apply as the Spotone products.

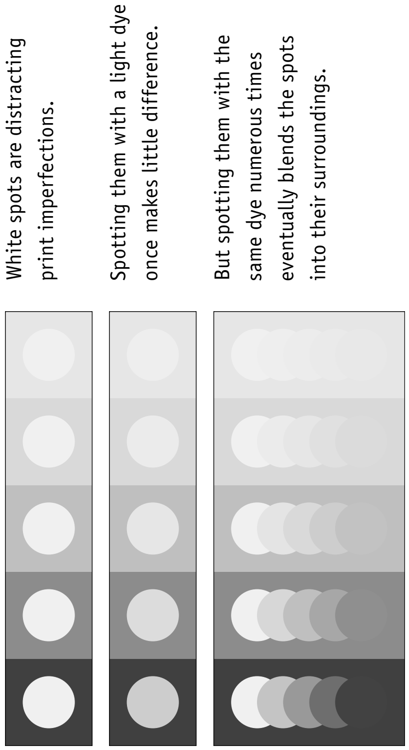

White spots are distracting print imperfections.
Spotting them with a light dye once makes little difference.
But spotting them with the same dye numerous times eventually blends the spots into their surroundings.

fig.4a A light dye is mixed and applied numerous times to carefully build up the tonality required to fill the spot.

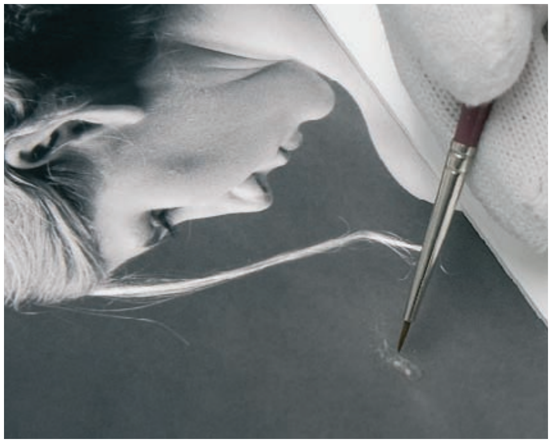


fig.4b Using a small brush to repeatedly apply a slightly darker dye to a series of lighter spots, a blemish is disguised and blends into the surrounding tones.

I would not hesitate to work with either of these ink-based materials. Conversely, I had little success with products containing egg white, shellac or other glazing agents and lacquers. Their ingredients are not absorbed by the print, but build a hard, shiny layer on top of the emulsion, similar to a coat of paint. They alter the surface reflection and make tonal blending far more difficult than with penetrating inks.

If you are concerned about photographic product availability in general and monochrome, fine-print products in particular, spotting dyes should be the least of your worries. In the absence of specially made retouching products, one is well-served with archival inks as they are used in drafting and calligraphic applications. You might even go back to the very roots of ink making and produce your own spotting dyes from solid India or China Ink sticks (fig.3c). Grind some ink off the stick, mix it with an equal amount of gum arabic and dissolve together in distilled water. Alternatively, fill an ink rubbing stone with some water, rub the ink stick against the stone until the water turns deep dark and add some gum arabic to it.

Gum arabic promotes the adhesion between spotting dye and print emulsion while also controlling the gloss level of the dye. Therefore, use more gum arabic for spotting glossy prints than for spotting matt prints, and always try to match the surface reflection

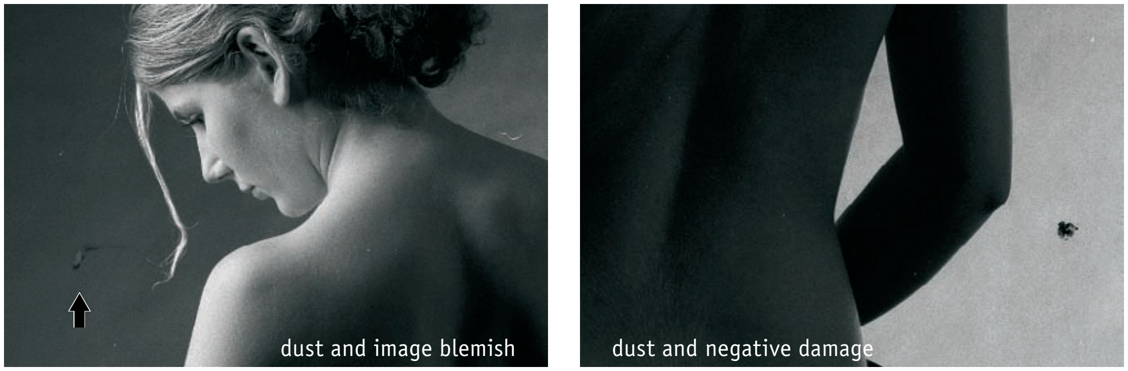


fig.5 An initial enlargement of the print revealed numerous imperfections of different origins. On the left, typical white spots and lines, caused by dust on the negative, are joined by a dark blemish (arrow), which was actually a tear in the paper of the studio background. On the right, there are more dust spots, together with a large dark spot, caused by a small emulsion defect in the negative.

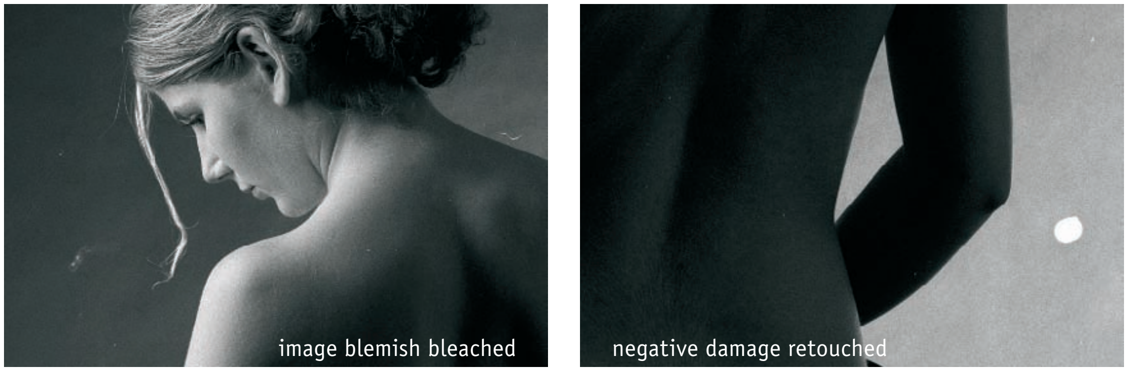


fig.6 After retouching the negative and turning the dark spot into a white spot (right), a new enlargement was made. The dark blemish, caused by the tear in the paper, was bleached with Farmer’s Reducer during wet processing until it was lighter than its surroundings (left). These actions eliminated the need for etching, and the print is now ready for spotting.

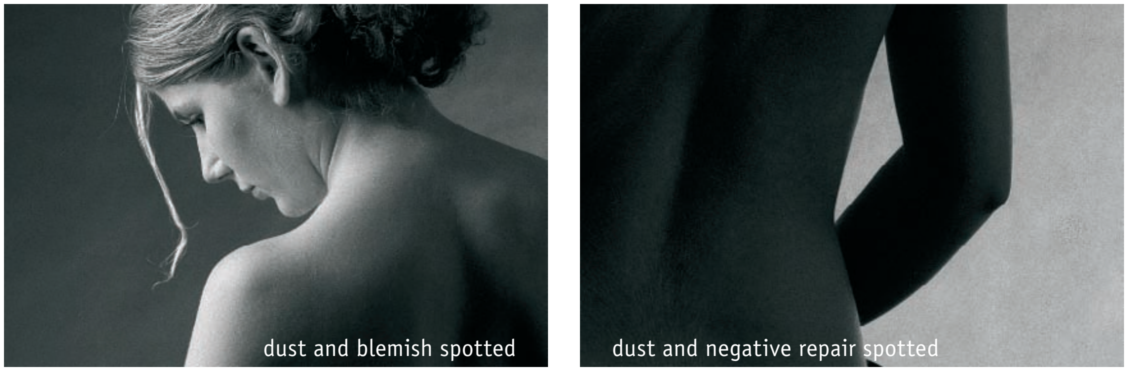

dust and blemish spotted
dust and negative repair spotted

fig.7 After making sure that all print imperfections are lighter than their surroundings, the print was carefully spotted. The goal is not to eliminate the imperfections altogether, but to move them from attention-grabbing boldness to inconspicuous obscurity. The telltale signs of spotting are only visible upon close inspection and by knowing where to look for them.

of the surrounding print area. Gum arabic can also be applied to professional spotting dyes in order to increase their inherent gloss levels.

Dark spots on the print create a unique challenge to retouching efforts. They cannot be covered up with spotting dyes, because the dyes are made to build up tonality in the emulsion and not to paint over it. One way to remove dark spots is to bleach the print locally, while still wet, until the area is slightly lighter than its surroundings and spot it back in when dry. This is rather difficult with dark spots approaching maximum black, in which case, the blemish is best removed by turning a black spot into a white spot first. This is done by covering the corresponding negative area with an opaque liquid on the substrate-side of the film. This way, what printed as a black spot now prints as a white spot and can be easily disguised through print spotting. Any damage to the print emulsion, which is

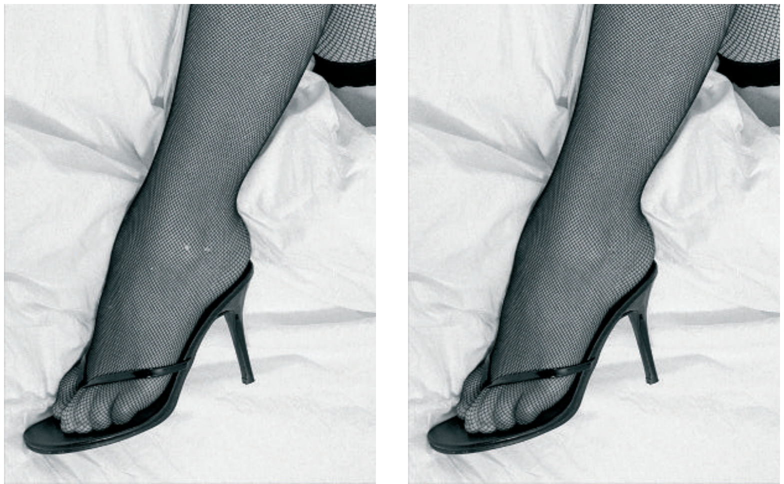


fig.8 Print spotting is not limited to removing dust and other print blemishes. As this example shows, it can also be used to retouch image-based imperfections. A few tiny holes in the stockings have been successfully repaired by simply correcting the damaged stitches with a small brush and some spotting dye.

an unavoidable result of etching, is prevented by this method. Special opaque liquids are on the market (see fig.3d), but any near-opaque ink will work as well.

## Print Spotting Process

Professional print spotting takes a lot of practice and experience, but it does not take too long to learn the basic steps and improve the appearance of a print significantly. The main challenge is to understand the need to resist the initial impatience. Print spotting is not something that should be done in a rush, or the results will look rushed.

I do all my spotting after print mounting, because this has the benefit of being able to work with a perfectly flat print. However, it has the disadvantage of potentially wasting a mount-board if something goes terribly wrong during spotting, a risk that gradually diminishes with increasing spotting skills.

Clean up your work area, and make certain that it is dry, uncluttered and dust-free. Provide for bright and even lighting and get a comfortable chair. Get a large magnifying glass or use extra-strong reading glasses in addition to your corrective eyewear. Have all your spotting tools and materials ready, put on your gloves and continue with the following general steps:

1. Place a single drop of undiluted spotting dye into the saucer or porcelain palette (see fig.2). Using a mixing brush and distilled water, dilute the dye and create several drops of decreasing strength.
2. Place a spare piece of mount-board on top of the print, close to an area that needs spotting. Start with the lightest spots and the weakest dye.
3. Dip the tip of your brush into a dilution significantly weaker than the spot seems to require.
4. Blot the wet brush tip gently against some blotting paper. You have more control over spotting with a dry brush than with a wet brush.
5. Carefully touch the print with the tip of the brush. Aim for the center of the blemish. Do not stroke the brush; you are spotting, not brushing.
6. Compare the first spot you made to the tone of the surrounding area. If it is darker, quickly blot off what you can before it dries, apply a drop of distilled water to what is left and blot that off too. Repeating this a few times will not remove the stain at all, but it will make it less obvious.
7. The first spot application should look significantly lighter than the surrounding area. The goal is to start with a light dye and gradually build up density. Spots that are too light are easily darkened, but spots that are too dark are hard to remove and can ruin an otherwise perfect print.
8. Once you have the correct tone of dye, hold the brush straight up, and keep spotting the rest of the blemish by repeatedly applying tiny spots until it is filled in. Again, do not paint, spot. Be patient, and give the dye time to dry between applications.
9. After the first blemish is completely filled in, examine the print for blemishes of similar tone, and spot them next. While working on increasingly darker spots, slowly increase the strength of the dye. Repeat this procedure until all print imperfections are sufficiently disguised.

### Final Hints

By far the most common spotting mistakes are to work with too wet of a brush and to use too dark of a dye. Until a certain spotting proficiency has been obtained, work with an additional copy of the print to practice and fine-tune the tonality of the dye, before spotting the actual print. When you feel more confident, simply use the trimmed white borders of the print itself to verify the tonality of the dye.

Correcting large blemishes takes a lot of tiny spots and effort. Resist the temptation to make larger spots. It quickly turns professional spotting into amateurish painting, and results will be perceived accordingly.

# Framing and Displaying Prints

## Fully protected and ready for the exhibition

A print's appearance is improved significantly through mounting and matting, and subsequent spotting provides the cleanliness every good print deserves. However, framing a print behind glass is the ultimate aesthetic enhancement. No matter how much impact the print has on its own, if left unframed, it will always look inferior next to its framed counterpart. It takes a significant amount of time and money to frame a print professionally, but it is well worth the effort and expense for all prints going on display. Skillful framing gives our best prints the attention they deserve and us an opportunity to proudly exhibit our work.

The purpose of a frame is to isolate the print from its surroundings, enhance it aesthetically and protect it against dirt, dust and rough handling. Always select a frame design and color that complement the print without drawing any attention from it. A good frame supports the print without dominating it. Make sure to exhibit the print and not the frame.

The effort involved to turn a print into a framed print must not be underestimated. Mounting, matting and framing enough prints to fill a small exhibition can take a week or two of labor, and the materials alone might cost more than a camera. If you decide to frame your own prints, it certainly makes sense to be familiar with the materials and procedures available for framing and to find the best local sources for your supplies. But, even if you decide to take your prints to a professional framer, a little background on suitable framing materials and procedures helps to negotiate the best deal. A good frame will keep the print safe and representable for years to come.

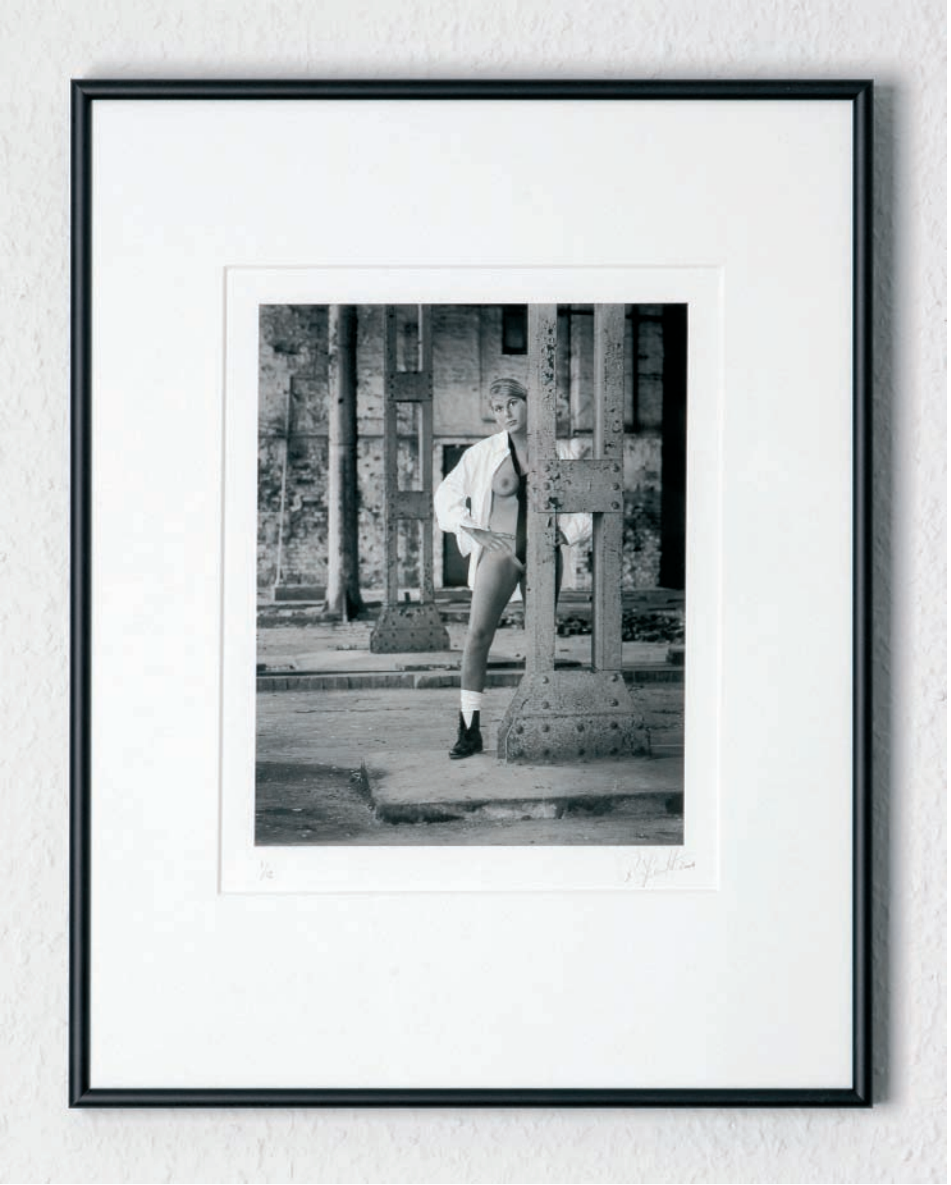


fig.1 A frame isolates the print from the wall, enhances it aesthetically and protects it against dirt, dust and rough handling. Select a frame design and color that complement the print without competing with it.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50010-7

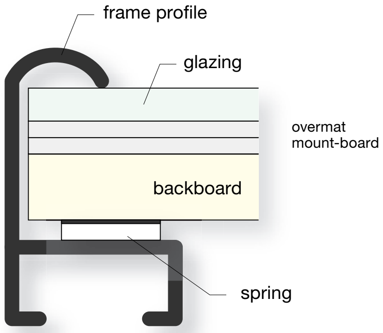


fig.2 Extruded aluminum profiles are the material of choice for professional framing. Here, the popular Nielsen & Bainbridge profile #15 offers enough room to comfortably fit one sheet of glass, two mat-boards and a backing board inside of it, while still leaving a gap to fit a number of springs, which later compress and securely hold the assembly in place.

fig.3 A print is put behind glass for protection, even though that degrades the print's appearance, because it slightly changes the image color and reduces image contrast significantly.

## Choosing a Frame

If we ignore all archival considerations, we are able to choose from an almost bewildering assortment of frame materials, including wood, metal and plastics. However, if we want to protect our photographs from harmful odors and fumes, the selection becomes much more limited. Wood contains aromatic oils, which vaporize over time and attack our photographs. Paints and varnishes emit harmful fumes, which do the same. The safest frame materials are chemically inert plastics and unpainted metals.

For aesthetic and chemical reasons, plastic frames are considered to be inferior and not suitable for high-quality framing. Mass-production plastic frames are often sold in combination with a cheap cardboard backing, which rules them out for archival reasons. This leaves us with unpainted metal frames.

Attention to weight, cost and corrosion issues make aluminum the professional frame material of choice. Extruded aluminum is light, relatively easy to cut and machine, and its smooth finish can be corrosion protected without paint. For all these reasons, I use anodized aluminum frames exclusively and committed to a personal standard of a matt black finish. The type of finish is a personal choice, but in my opinion, a thin black frame is the perfect companion for a white or light-gray overmat, creating enough contrast to clearly isolate it from the wall and quietly continue the style of the black and white photograph all the way to the edges of the frame. When a print is framed this way, and exhibited alongside others on a white wall, it always comes across as a well-coordinated, professional design concept that one can be proud of.

A secondary consideration when choosing a frame is the selection of a suitable profile. Except for appearance of the exposed contour and a choice between smooth and sharp edges, this is mainly a matter of package requirements to fit the glass, mounted print and the backboard. Nielsen & Bainbridge, a well-known manufacturer of mounting and framing materials, offers a popular profile design called '#15'. It is about 1 inch tall and provides a 15mm pocket inside the profile to comfortably fit a 2mm sheet of glass, two 4-ply mat-boards and a 1/4 inch backboard, while still leaving a gap to fit a number of springs, which later compress and securely hold the assembly in place. Several framing material suppliers have copied this profile with only minor modifications.

## Glazing Considerations

A print is always put behind glass to protect it, but without exception, this degrades the print's appearance to some degree. Still, framing without glazing is not an option to me. Too high is the danger that innocent or careless, greasy fingers will find their way to the print's surface, leaving possibly permanent fingerprints or scratches. A thin sheet of glass protects the print against thoughtless touching, unavoidable dust, and accidental transport damage, scuff marks, rough handling, temporary pollutants and UV radiation. In other words, the glass protects against all the typical dangers a print faces when we are not there to guard it. To avoid playing sentry, I am willing to accept that a print behind glass does not show its full splendor.

A print behind glass suffers from a slight change in color but mainly from a noteworthy loss of contrast. It is worthwhile to understand how the optical properties of a particular picture glazing material affect the image contrast. If perfect glazing material existed, it would be invisible, transmitting all light and absorbing or reflecting none. Unfortunately, perfect glazing does not exist, and we have to deal with reflections, absorption and a loss in transmittance.

A significant portion of the light is immediately reflected off the glass surface (8%), and depending on surface smoothness, specular or diffuse reflections are created. The remaining light makes its way through the dense glass material, and some of it is absorbed along the way (2%). What is left (90%), is the light transmitted by the glass (fig.4). Light absorption acts like a mild filter, which has a slight impact on color appearance, but this is usually of little concern. Light reflections and the loss in light transmittance, on the other hand, have a noteworthy effect on image contrast, changing print appearance in different ways.

A loss in transmittance dulls print highlights. Bright highlights (Zone VIII) reflect about 81%, and dark shadows (Zone II) reflect just over 1% of the light they receive, which makes for a difference (or contrast) of roughly 80%. Observed behind glass, the brightness values of highlights and shadows are reduced, because the glass transmits less than 100% of the light reflected by the print. This affects highlights and shadows by the same percentage, but in absolute values, highlight brightness is reduced more than shadow brightness. For example, at 90% transmittance, Zone-VIII reflection drops to 73% and Zone-II reflection is still above 1%.

Consequently, the image contrast drops to 72%, almost entirely due to a loss in highlight brightness. At 80% transmittance, image contrast is reduced to 64%.

The image contrast is degraded further through light reflections off the outer glass surface, because reflections dull image shadows more than image highlights. That is to say, uniform exhibition lighting has a non-uniform effect on print highlights and shadows, because adding some light to bright areas is less noticeable than adding the same amount to dark areas. Let's assume that a framed print is observed from a direction at which 4% of the exhibition lighting is reflected off the glass. Adding this 4% reflection to a Zone-VIII highlight lifts its brightness by just 1/3 zone. Adding the same reflection to a Zone-II shadow catapults its tonal value by two zones to Zone IV. This contrast loss must be avoided by carefully considering the position of all display light sources. The combined effect of reflections and reduced transmittance is easily demonstrated by covering a portion of a print with a sheet of glass, as shown in fig.3. The uncovered, unprotected print area clearly exhibits more image contrast and brilliance.

Within limits, it is possible to battle the reduction in image contrast by preventively increasing the contrast of prints intended to be shown behind glass. For example, a negative, typically printed at grade 2, is purposely printed at grade 2 1/2 to compensate for an anticipated contrast loss of 10% behind glass.

Compared to the potential danger of damaging the print, a small degradation in print appearance is of no concern. However, to get the optimum compromise between protection and visual degradation, we need to choose an appropriate glazing material.

### Plastic Glazing

Typical plastic glazing materials are polycarbonate and acrylic, often called by its trade names Plexiglas or Perspex. Of the two, acrylic glazing offers less UV protection but transmits up to 90% of the light it receives, which is comparable to regular glass (fig.5). Polycarbonate is more resistant to impact and absorbs more UV radiation, but yellows within years if exposed to sunlight and transmits only 80% of the light. Consequently, acrylic is the preferred plastic glazing material for picture framing, and is used instead of regular glass whenever shatter proofing and weight are serious considerations. Hence, it is recommended for shipping framed prints and wherever there is a chance of prints falling off the wall, as with small children. However, it must always be coated with a specialized foil to filter harmful UV radiation and fully protect the print.

Nevertheless, acrylic surfaces have a propensity for attracting dust and cannot be cleaned with regular glass cleaners. In addition, due to their inherent material properties, they are never perfectly flat when upright and suffer from waviness with temperature fluctuations. This waviness takes away from a professional presentation and limits its use to exceptions.

### Transparent Glass

Regular transparent glass, also called float glass, is a pane of glass manufactured by floating molten glass on a bed of molten tin. The float glass process was pioneered by the well-known British glass manufacturer Pilkington in the 1950s, and this relatively recent manufacturing technique makes it possible to create an even sheet of glass of uniform thickness and with absolutely smooth surfaces.

Float glass is inexpensive, easy to clean, impermeable by harmful pollutants and fumes, insensitive to variations in temperature and humidity, always remains perfectly flat, and it is far more resistant to scratches than plastic glazing. This makes it a prime candidate for protecting framed images, and since modern window glass is also made from float glass, we can easily obtain the required supplies at any local glazer.

Float glass provides adequate UV protection (fig.5) and has a transmittance of just above 90%. Of the remaining 10%, roughly 2% are absorbed, and 8% of the light is returned as a specular reflection (fig.4a),

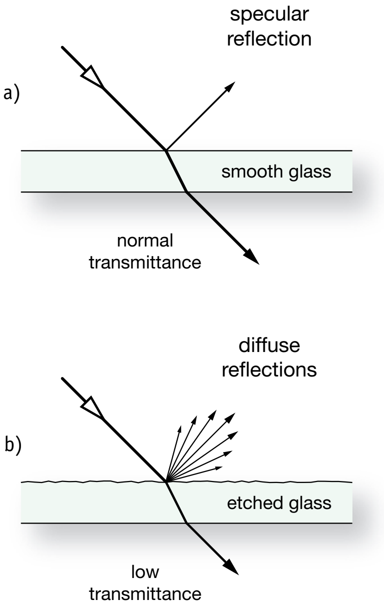


fig.4 A significant portion of the light is reflected off the glass surface, and depending on surface smoothness, specular or diffuse reflections are created. The remaining light is either absorbed by the dense glass material or transmitted through it.

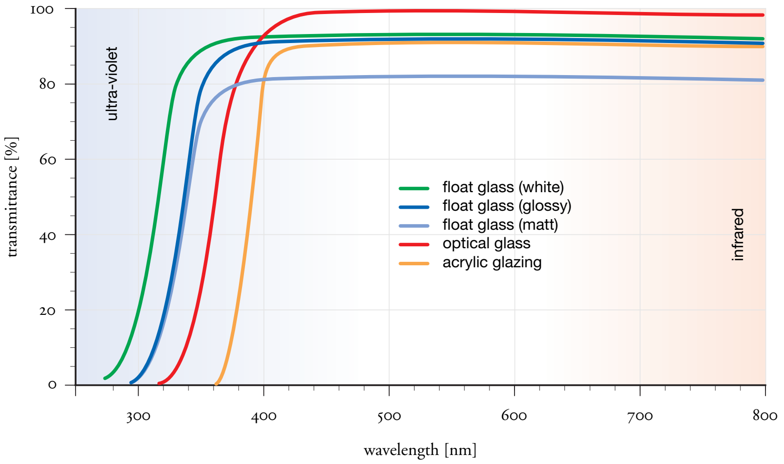


fig.5 Typical picture glazing materials differ in light transmittance and the amount of UV protection they provide.

which, depending on the lighting situation, can obscure viewing the image. A possible countermeasure is non-reflective picture glass. This is also made from regular float glass, but one surface is chemically etched to mildly roughen the surface and diffuse reflections, similar in effect to the anti-Newton glass used for slide frames or negative carriers (fig.4b). This does not affect the UV protection, but it has the disadvantage of reducing the light transmittance to about 80%.

An alternative is to use a specially made, white float glass. Pilkington sells such a float glass under the brand name Optiwhite. White float glass has a reduced iron content, which eliminates the faint yellow or green tint, otherwise observed in regular float glass. This increases the light transmittance slightly but, unfortunately, also reduces UV protection (see fig.5). Overall, a print behind white float glass is more neutral in color and exhibits a bit more contrast than a print behind regular float glass. But, in the long run, I don't think that this minor viewing improvement is worth the risk introduced with increased UV exposure.

A much better, but very expensive, glazing alternative is to frame the print behind white optical glass. This is similar to the glass used in camera or enlarging lenses. Its special anti-reflection coatings increase the light transmission to 99%, while eliminating reflections almost completely and improving UV protection, compared to regular float glass (see fig.5). Under normal lighting conditions optical glass is hard to detect and almost invisible. Schott, another well-known glass manufacturer, markets an optical picture glass under the brand name Mirogard, but its prohibitive cost typically limits its application to luxurious galleries and well-subsidized museums.

For my own framing work, I stick to thin, regular window glass. It's a cost-effective compromise with only minor disadvantages. But, regardless of the kind of glazing you select, a print must never be placed directly against the glazed surface, or the emulsion will make contact with the glazing. This combined with normal humidity levels is sufficient for the gelatin emulsion to swell and eventually stick to the glass surface, in which case, separating the print from the glass will be close to impossible, and the print is most likely lost. This cannot happen, of course, if you use a standard overmat. The overmat provides an adequate gap between the print and the inner glass surface, making a touch condition impossible.

### Glass Cleaning

When I receive my glass from the local glazer, it is not clean enough to be used right away. Coming out of his workshop, it is full of dust and fingerprints and needs a thorough cleaning before it can go into the frame. But, getting glass perfectly clean is not an easy task.

Before placing the sheet of glass on top of a flat work surface, brush off loose dust and dirt from all surfaces to avoid scratching the glass during cleaning. Then, spray a small amount of commercial glass cleaner onto one side of the glass, and use a clean towel to remove all dirt until there is no cleaning fluid residue left. Repeat if necessary, always using a fresh section of the towel, otherwise the dirt is not removed but only distributed. After both sides seem to be clean, check their actual cleanliness by observing the reflections from a nearby lamp in the glass.

All commercial glass cleaners contain potentially harmful chemicals, including acids, ammonia, dyes and fragrances. We might need some of them to effectively clean the glass, but we don't want any cleaning residue within the confines of a frame and archivally processed prints. That's why I go through the extra effort and clean the print-facing side of the glass again with distilled water and another fresh towel.

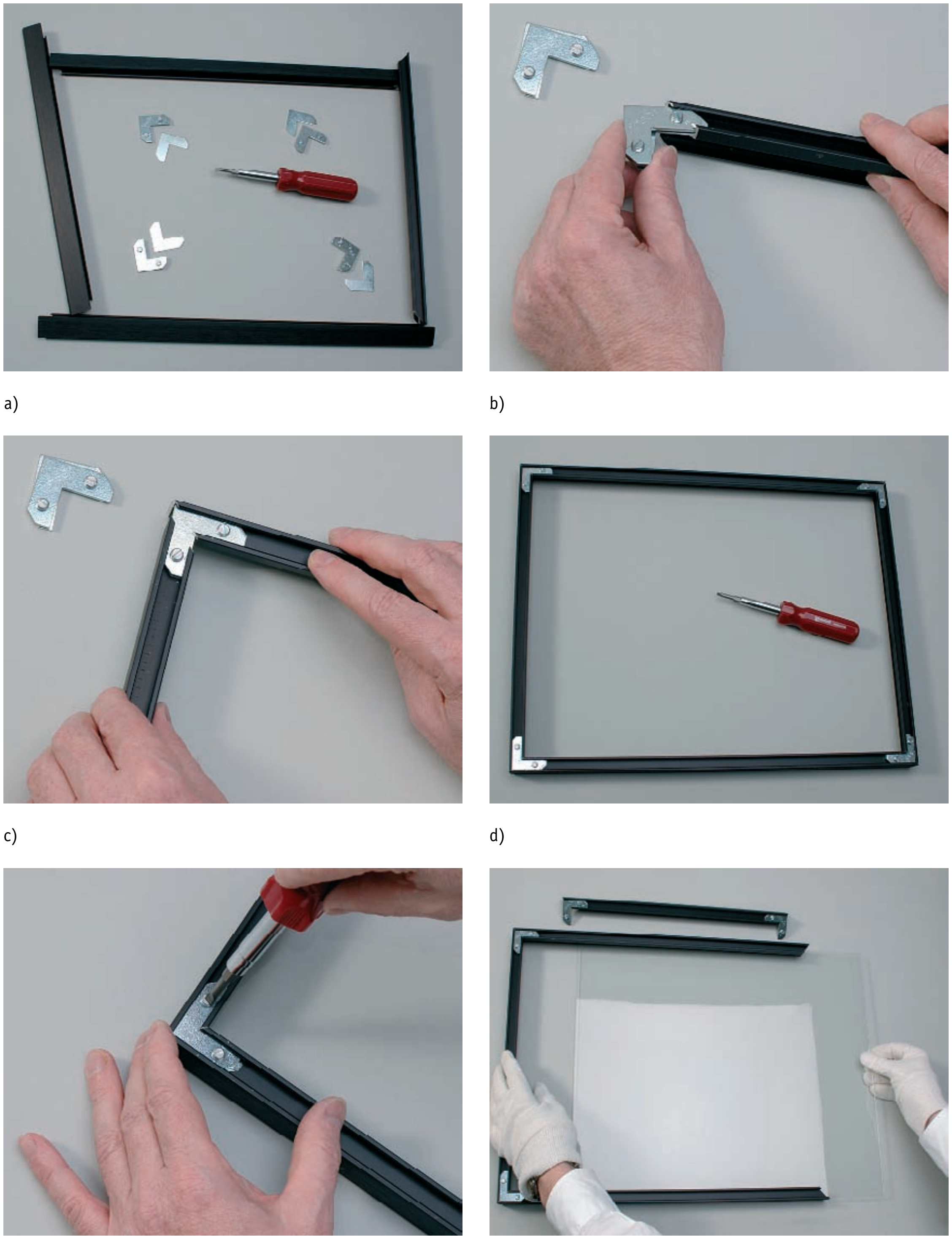
## Framing Techniques

The right frame is often a compromise between quality, cost and convenience. Mass-production frames can be purchased ready-made in a number of standard sizes, but they usually do not meet archival standards. Custom-made frames, put together by a professional frame shop, have any quality level you are willing to pay for. They are also a very convenient but never the least expensive option.

High-quality framing at the lowest cost requires you to do the framing yourself. Two framing options are introduced in this chapter: first, a more permanent framing option, which I use for purchased prints, and second, a unique reusable framing option, which I recommend for print exhibitions.

### Permanent Framing

This is a very reliable framing option for all prints that are intended to go on permanent display. Over the next few pages (fig.6-9), you will find step-by-step instructions to put these frames together. As you will notice, this framing method is not as irreversible as



a) b) c) d) e) f)

fig.6 a) Cover the work surface with a spare piece of mounting board and brush it off to provide a clean and smooth work surface. Get four pre-cut frame profiles, all double-plate corner hardware and a screwdriver ready.

b) If not already done, assemble the double-plate corners, and adjust the screws, so that the corners snugly fit into the open profile.

c) Insert a hardware corner for each corner of the frame, and continue loosely connecting all profiles, thereby closing the frame, but do not tighten the double-plate corner screws yet.

d) At this point, the frame is still only loosely assembled, but the corners of the frame are at almost perfect right-angles.

e) While firmly pressing the miter joints together with your fingers, tighten all screws, and then, turn the frame around to verify the accuracy of the joints.

f) Loosen two screws again, to open the frame on one side, and slowly insert a clean pre-cut sheet of glass all the way into the open frame. The white tissue shown was used to separate the glass sheets during storage, keeping them free of scratches. Always wear protective gloves when handling glass!

fig.7 a) Take advantage of this last opportunity, and clean the print-facing side of the glass one more time, making sure that every tiny dust particle is removed.

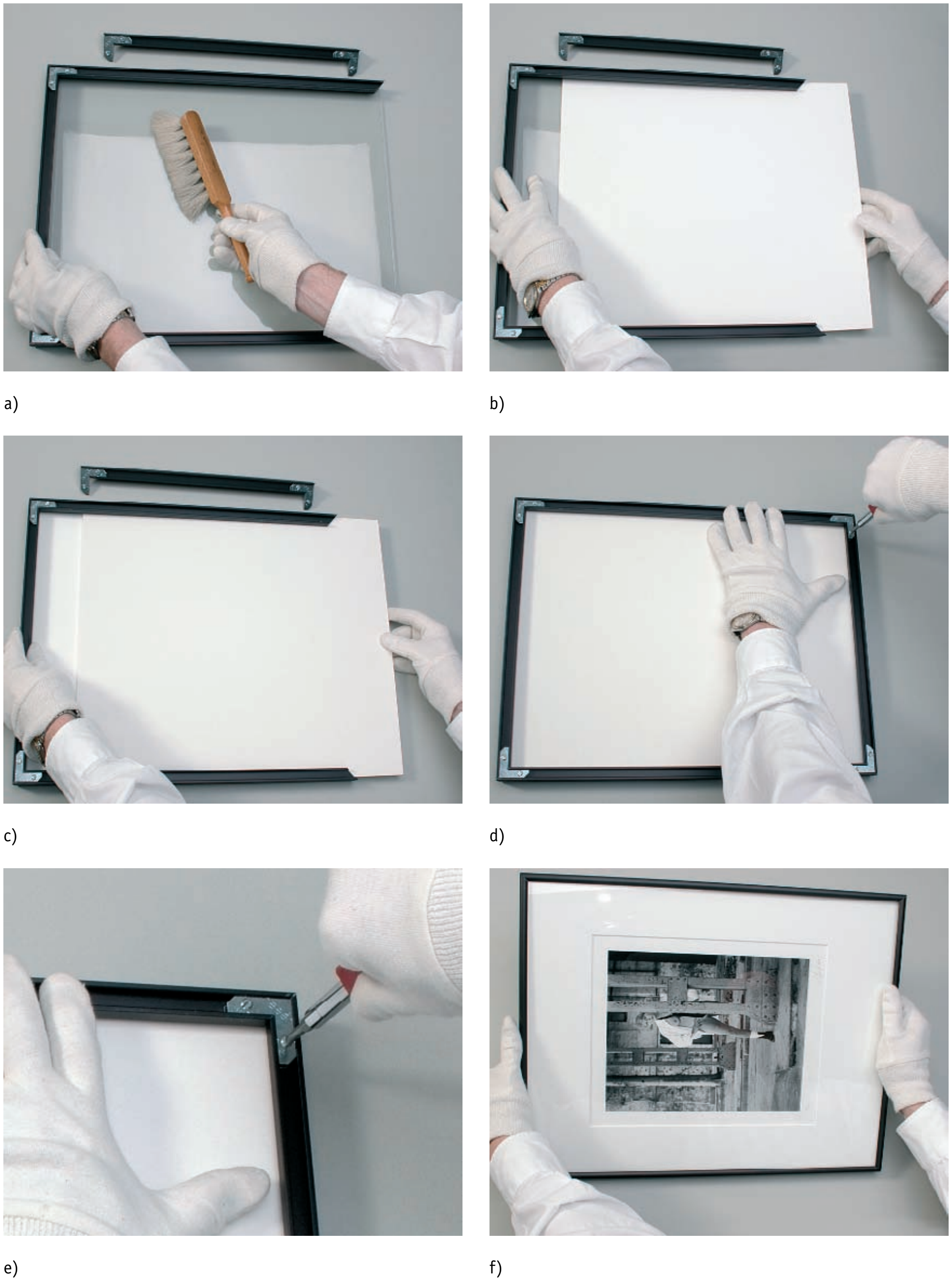
b) While inserting the mounted and matted print facedown, be sure to lift the boards slightly, otherwise the window cut of the overmat may catch on the edge of the glass and ruin the mat.

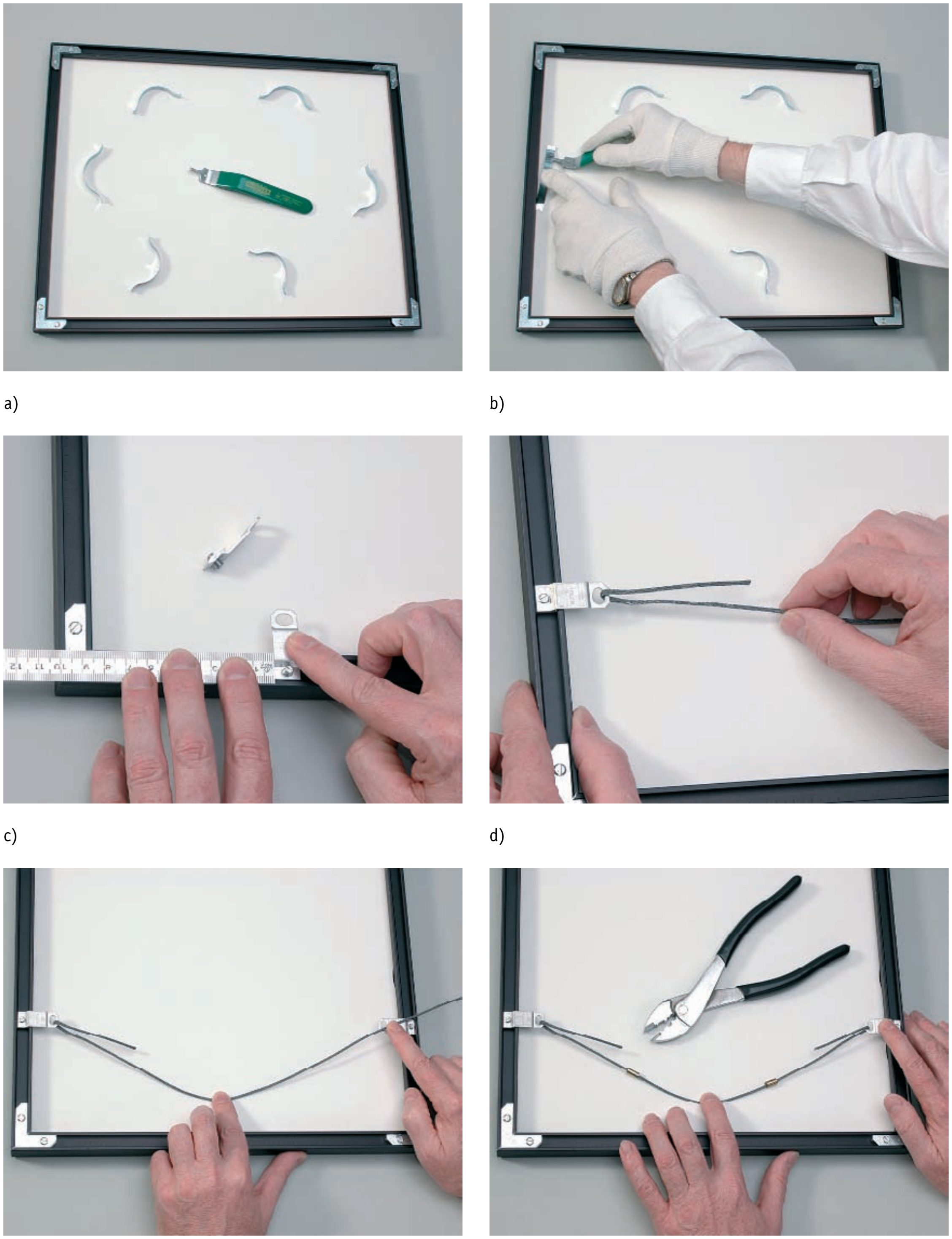
c) Insert a pre-cut, acid-free, 1/4-inch-thick backboard made of foam core. It supports the mount from the back and presses uniformly against the glass, holding the print always nice and flat.

d) Unless you choose to add an additional plastic sheet as a pollution barrier, which may only trap humidity and cause more problems than it is worth, close the frame and tighten all screws carefully.

e) Remember that you are dealing with a relatively thin aluminum profile. The corner screws are very strong and easily over-tightened, which will ruin the frame.

f) Before clamping and fixing the print assembly into place, carefully inspect the print and mount-board for dirt and dust, accidentally left behind, in which case you need to open the frame one more time to remove it. Otherwise, this is the last opportunity to fine-tune the final print position inside the frame.


a) b) c) d) e) f)



a) b) c) d) e) f)

fig.8 a) Six metal bow springs firmly hold an 18x22-inch print assembly in position. Positioning these springs, however, can be a tricky task. Fletcher makes a specialized product called Spring Mate, which is the perfect tool for this job.

b) Insert one end of the spring into the tip of the Spring Mate, and push the other end into the aluminum profile. Then, while turning the tool, push the entire spring into the profile. Distribute all other springs evenly. Don’t do this without safety glasses!

c) The next step is to attach two screw-fixed hangers. They are loosely inserted into the profile first, and with the aid of a ruler and a screwdriver, slid and then fastened into a standard position 100 mm from the top of the frame.

d) For solid support, which does not stretch or leave unsightly marks on the wall, use a 1.5mm braided stainless-steel picture wire, push one end of it up to 3 inches through the eye of the hanger, and bend it over.

e) With your left index finger, position the wire to the approximate future position of the nail, and cut the wire to a length that allows for a symmetrical wiring setup.

f) Unprotected, the bare ends of the picture wire are a potential source of painful finger injury. These sharp ends are stylishly covered by crimping them to the main wire, using a pair of brass ferrules. Before bending over the second end of the picture wire, slide two brass ferrules onto it, and get a pair of crimping pliers ready.

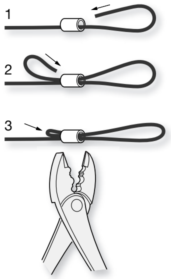


fig.9 a) Covering the sharp ends of the picture wire with neatly crimped ferrules adds a professional touch to framing. Pass the end of the wire through and back through the ferrule before crimping it tight. The inside diameter of the ferrule should be approximately 2.5 times the outside diameter of the wire for a snug fit.

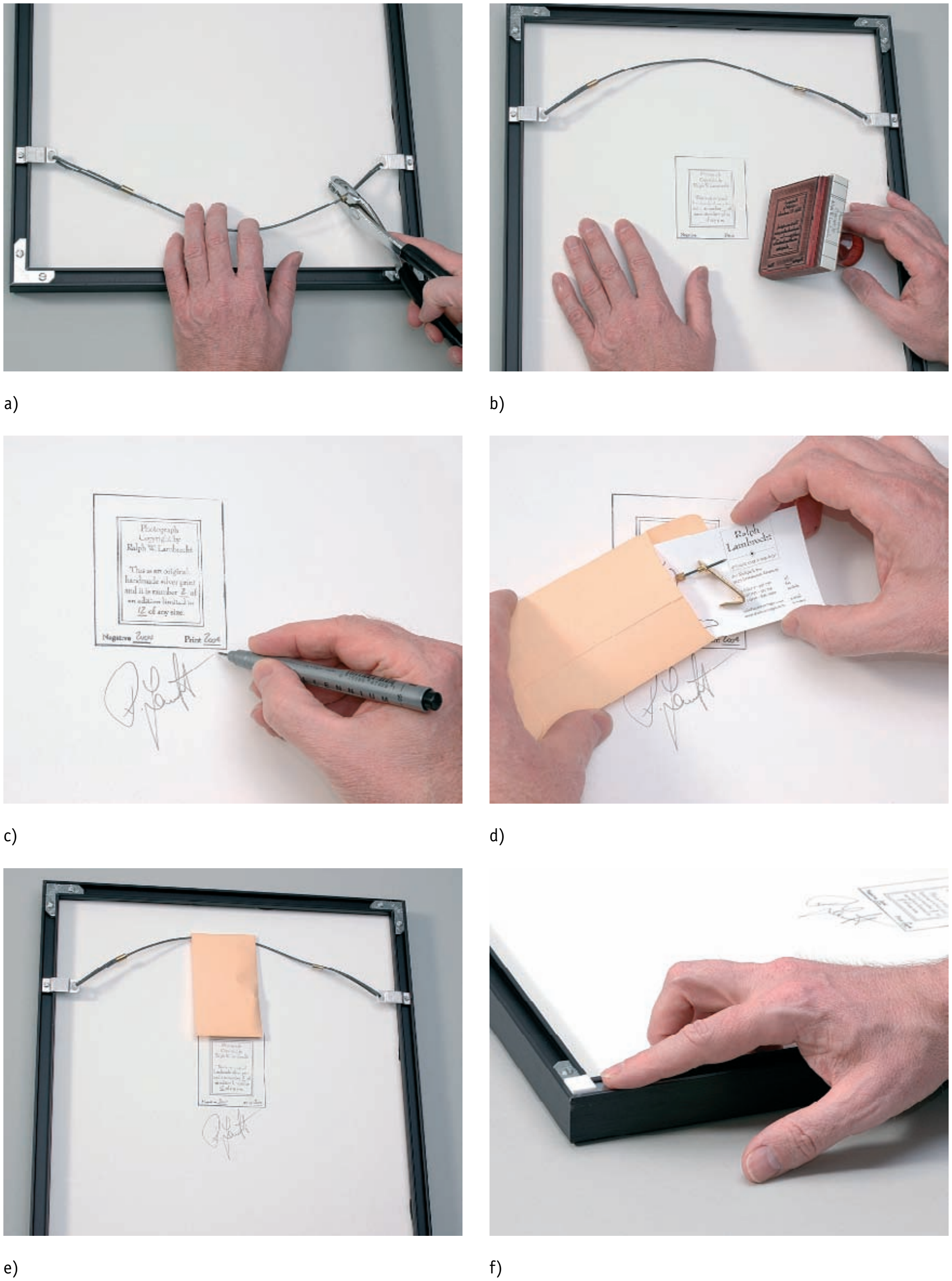
b) It is useful to have a custom-made rubber stamp, which contains all your standard, print identifying information.

c) Stamp the backboard with your customized stamp, sign it and complete the missing print information using an acid-free pen.

d) You can add perceived value to a framed print by adding your calling card and an elegantly shaped hook and nail.

e) Insert the calling card and the hanging hardware into a small mailing envelope, and glue it shut around the picture wire, so it cannot get lost.

f) As a final touch, glue a small plastic or felt bumper onto the back of each bottom corner of the frame. The bumpers prevent the frame from marking the wall, and they also reduce the frame from slipping along the wall, making frame leveling a less frustrating and more permanent task. The framed print is now presentable and ready for display.



the term might imply, but compared to other framing options, the result is perceived as providing much more than just a temporary home for the print.

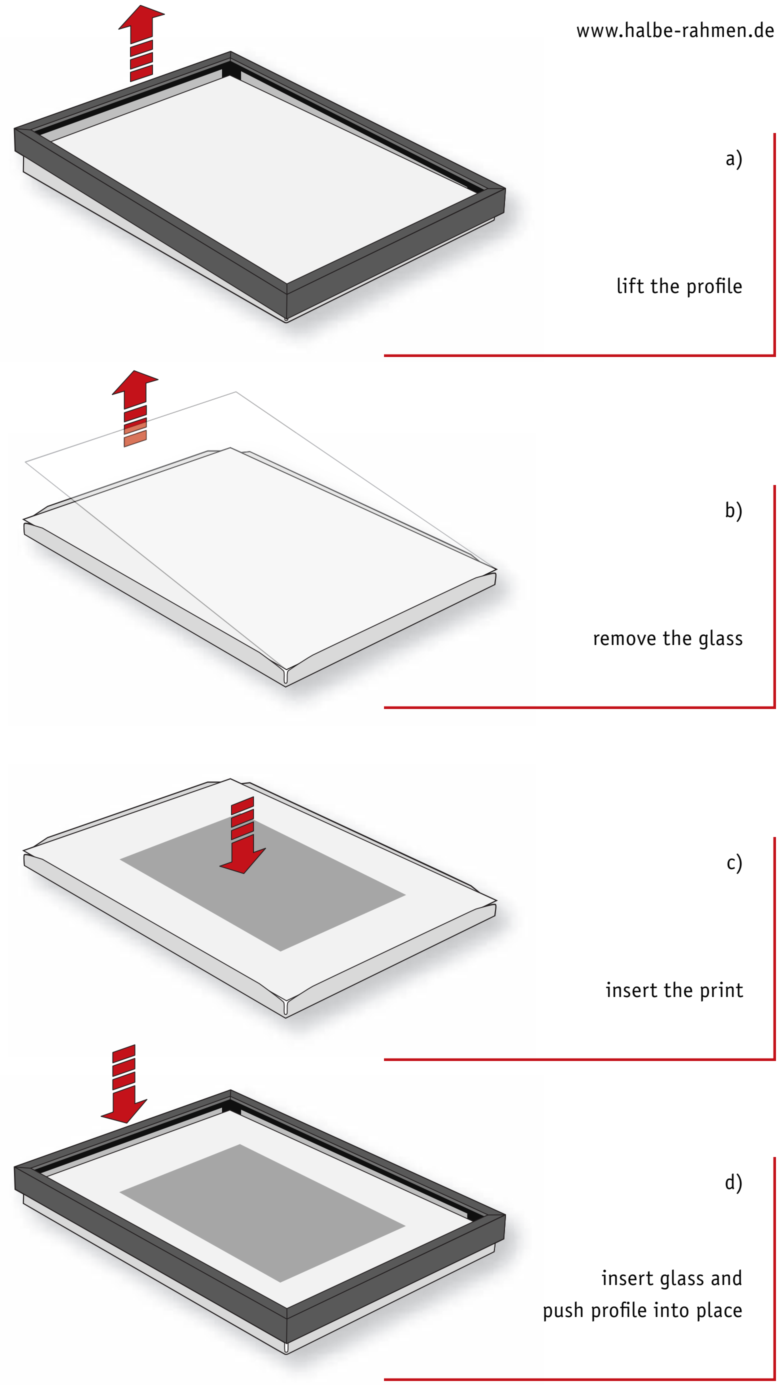
Permanent framing, in combination with Nielsen aluminum profiles, is the most popular choice of serious amateur and professional photographers in North America. Many established black and white photographers use it almost exclusively. The reason may be that Ansel Adams taught this framing method to his students, who in turn, continue to teach it to their students. Nevertheless, it is also a framing technique used by first-class museums and galleries, because it fully complies with archival standards if proper framing materials are selected. Other benefits include the durability and flexibility to match any print size and proportion, and the profiles required can be bought as pre-cut pairs or ordered to length.

Unfortunately, permanent framing also has a few disadvantages. You need several tools to get started and some special hardware, which usually fits only one brand of profile. In addition, permanent framing requires an additional backboard to support the mounting-board and overmat from the back. The backboard must be made of acid-free, 1/4-inch-thick foam core, to provide a uniform pressure against the glass, making sure the print is always held nice and flat. Another disadvantage is the time it takes to put the frame together. This is of no concern when framing the occasional print at your leisure, but when you are in a hurry, because you are getting ready for an exhibition, there is never enough time.

### Reusable Magnetic Frames

With permanent framing, every print belongs into its own frame. Exchanging a print with another is possible but cumbersome. Permanent framing is a time-consuming and expensive undertaking, and some photographers are looking for more flexibility. This is especially true for photographers who prefer to ‘rotate’ their prints through a limited number of frames or frequently put a themed exhibition together from a larger body of work.

For these occasions, a reusable frame is a better choice than a permanent frame. In 1975, Heinrich Halbe invented and patented a reusable frame in Germany, and his company has manufactured these unparalleled magnetic frames in standard and custom sizes ever since. The Halbe magnetic frame allows



www.halbe-rahmen.de

fig.10 Professional framing can be done in just a few steps with a magnetic frame. First, the profile is detached by simply lifting it off. Then, the glass is taken out, the print is inserted and the glass is put back. Finally, the profile is pushed into place, where it will adhere magnetically to the metal base. It is that simple!

If you are lucky enough to live in the UK, you can order all your framing supplies at Lion in Birmingham (www.lionpic.co.uk). In any case, it's worth taking a look at their website to get an idea of all the materials and tools available for professional framing.

fast and simple framing from the front, ensuring maximum convenience and flexibility (see fig.10). It is now one of the most popular professional framing concepts in Europe.

The magnetic coupling is the foundation for all Halbe frames. Every Halbe frame consists of three main components: the base element, the glass and the aluminum profile. The base element is a combination of a dimensionally stable, hard-foam backboard and a sheet-metal base. Projecting edges in the sheet metal allow the mounted print, overmat and glass to be quickly inserted and securely fixed. The pH-neutral, hard-foam backboard is PAT-tested by the Image Permanence Institute (IPI). It provides perfect flatness and has a white, acid-free paper layer in the front and back, as well as a hidden aluminum barrier to protect the print against humidity. Several magnetic strips on the inside of the aluminum profile ensure that the frame adheres fully and reliably to the base element.

A mounted and matted print is professionally framed in just a few steps. The aluminum profile is detached from the base element by simply lifting it off, while simultaneously pressing against the glass to hold the base element down. Then, the glass is lifted out of the base element, the print is placed onto backboard, and the glass is inserted again. To finish framing, the aluminum profile is pushed into place, where it adheres magnetically to the sheet-metal base. It is that simple; no tools or hardware required! The print is securely positioned, perfectly framed, and it can be replaced just as quickly.

## Exhibition

All photographs are made to be seen; outstanding photographs are meant to be exhibited. There is little sense in going through all the work and expense of creating prints to then hide them from public view at the bottom of a filing cabinet, or with digital images, in the obscurity of a computer directory. No matter if you are limited to a single wall in your own house, where only you and your visitors can enjoy your images, or if you already belong to the selected few who are invited to have their own exhibition on public display, it seems logical to include a few helpful remarks on how to effectively present framed prints.

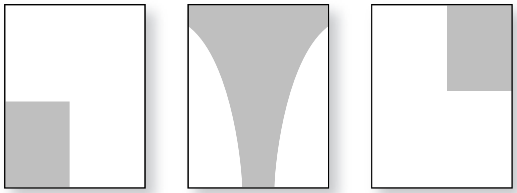


fig.11 Due to its individual composition, each print within the panel can be classified as being a left, right, top, bottom or center print. This can be taken as a clear recommendation for the print's most or least effective position within the panel.

### Designing a Panel

With the possible exception of Leonardo's Mona Lisa, prints are usually not exhibited individually. Most photographers select what they perceive as their best prints, and use them to create a representative display of their work. However, that's not necessarily the best way to design a successful exhibition! Individual photographs may have all it takes to create an admiring audience, but viewed in combination with other prints, they might not get the attention they deserve, or worse yet, they may be clearly out of place.

A panel of prints is a coherent display of a number of images (fig.12). Careful attention must be given to any print that is considered for the panel. Sensibly done, different print sizes and some print styles, as in high or low-key, can be convincingly combined to make for an attractive panel. But in general, each print must fit a common theme and must be printed, toned, mounted and framed in a style matching the other prints. This is an easy task for photographers who have already established their own, uniform workflow, because their prints will already have a common 'signature'. However, photographers still experimenting and in search of their own style must be aware to never mix different toning efforts, mount-boards or frames within one panel. A panel is not a display of the photographer's multi-talented capabilities or lifetime accomplishments. A well-designed panel is a successful piece of art in itself.

Once a number of complementary prints have been selected to be combined into a panel, an effective print arrangement has to be found. Taking a closer look at each print quickly reveals that some are more suitable for a certain location within the panel than others. For example, the top left-hand corner print in fig.12 would not fit well into the bottom right-hand corner of the panel. Choosing that location would force the model to look out of the panel and disturb the overall impression. A similar consideration applies to the current bottom right-hand corner print. This is the most effective location within the panel for

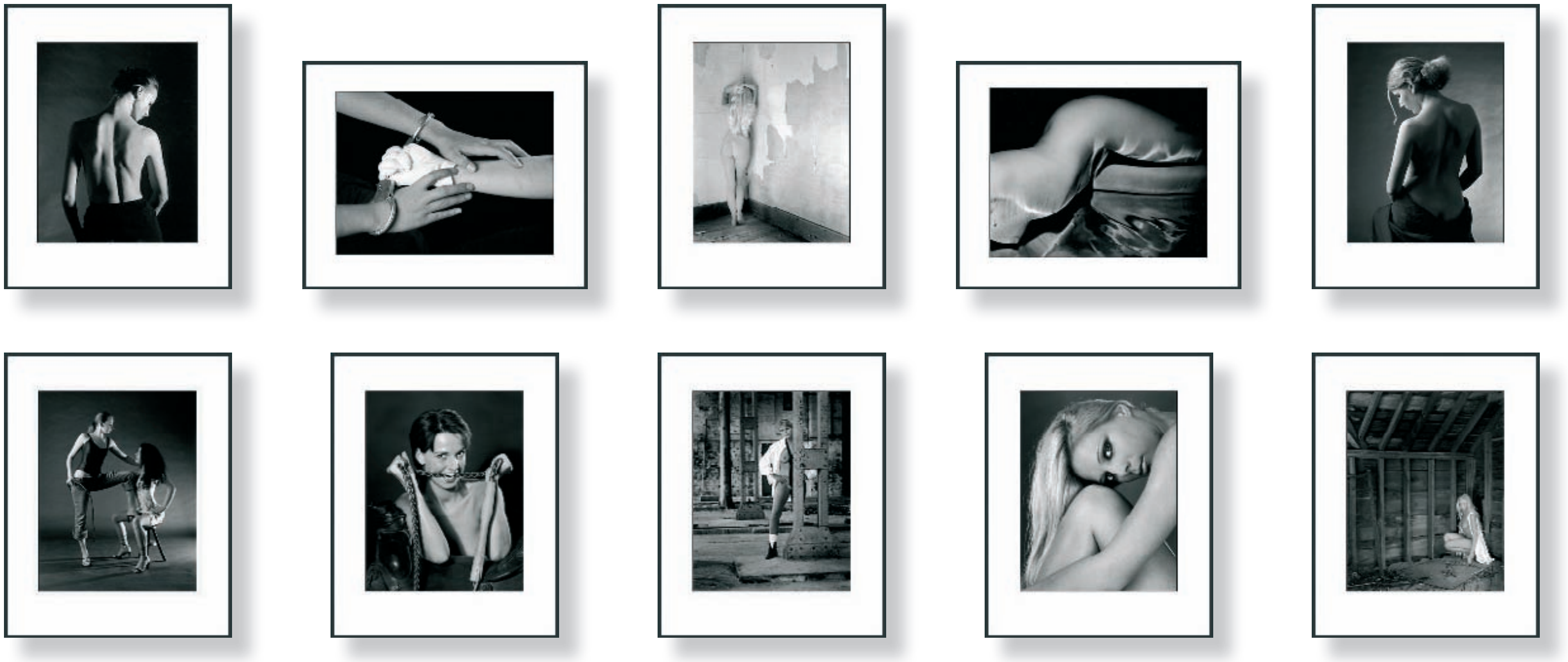


fig.12 A panel of prints is a coherent display of a number of images. Careful attention must be given to any print considered for the panel, because each print has to fit a common theme and must be printed, toned, mounted and framed in a style matching the other prints.

this particular print, because of its center of interest. A similar example of this is the top-row center print. Because it is a borderline high-key image, it has to be in the center to maintain a tonal symmetry within the panel. Some prints, however, could be located almost anywhere within the panel. The image in the bottom center is a very good example of such a print.

Based on its individual composition, each print within a panel can be classified as being a left, right, top, bottom or center print. Observing each print independently and locating its center of interest, which is the area of the print that catches the attention first, helps to identify the print's best and worst position within the panel. Fig.11 illustrates how this can be done in abstract terms, but turning the print upside down and looking at it for just a split second will also assist in doing this. With a bit of experience, you will be able to consider a print's admission to the panel and its potential panel position at the same time.

### Designing the Exhibition

An exhibition is an opportunity for a photographer to show his or her work. This is reason enough to ensure that everything concerning the exhibition is as good as it possibly can be. Unfortunately, you will not always be able to control every aspect of the exhibition, and you may have to make some compromises, but make sure that everything you can control is absolutely perfect. This also makes it easier to convince others to do their part as well.

First, make sure your panel is totally in line with the announced theme of the exhibition. Only display prints that look like they belong together, and make certain that they are all carefully spotted. No matter how interesting your images may be, or how much impact your prints may have, unspotted prints suggest technical incompetence. The same is true for print mounting and matting. Dirty mount-boards and raggedly cut overmat windows have no place in an exhibition. Inspect the frames to avoid chipped paint and scratches, and verify that prints and overmats are properly aligned and secured. Clean the glass to remove all dust and fingerprints, and handle the frames only when wearing gloves.

If you have control or influence over the exhibition facilities, consider the following criteria. White or light gray walls work well in conjunction with monochrome photographs. Make sure the frames are level and securely fastened to the wall at about eye-level height. If you are also able to secure a location with bright, even lighting, and without annoying reflections, your exhibition is off to a good start.

# What Size Is the Edition?

## Should I only make a limited number of prints from each negative?

by Brooks Jensen

Every time I'm involved in a workshop, there is a predictable series of debates that crop up: "Is it better to meter for Zone II or Zone III? Can a decent print be made on RC paper? Is photography really art?", and one of my favorites: "Who was the greatest photographer of all time, Ansel Adams or Edward Weston?" To workshop students who have never endured these debates, such topics, I'm sure, seem exciting and full of mystery, worthy of monopolizing the valuable time in a workshop. To anyone who has been around workshops for a while, these questions immediately inspire a yawn and the need to get away for a walk on the beach. There is, however, one question that I believe is worthy of discussion because it's a practical question that influences the photographer's entire career: "How many prints should be made of a given negative, and should they be limited and numbered?"

Heart Lake, 2008
WINTER TREES III

Thorny issues, like roses, are often best handled with protective gloves. The problem with gloves, of course, is that they both protect and numb. I stand accused and guilty of being numb about the issue of edition sizes to the point where I was unwilling to take a stand based on some underlying principle. In truth, I've struggled with the question of edition size for quite some time. I have politely avoided the issue, because I was not certain of my own position. Having thought about it a great deal now, for more than 25 years, my position on edition sizes has clarified. I am now prepared to take off my gloves (fully aware of the combative double meaning in such a phrase) and take a stand. In short, I've decided, I am against limiting an edition, period. Let me be specific: I am against a predetermined limit imposed as a strategy to make the artwork scarce. I am now prepared to say that '1/250' is a bunch of bull.

To begin this chapter, I'd like to make a case for not limiting the size of an edition in the hopes that my thought

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50011-9

process might be useful as you think through this issue for your artwork. There are, of course, two sides to consider in any debate such as this. There are those (I assume many of you reading this chapter) who will vehemently disagree with me. My challenge is to persuade you, and I will attempt to do so by considering, one by one, the arguments for limiting editions.

I should add parenthetically that this chapter fairly accurately portrays my internal vacillations about this issue. There have been times when I leaned toward limiting, and other times when I have leaned away. It was only after considering each of the points that follow that I finally came to a firm stance. In some regards, I hope even this process adds value to your consideration of this issue.

## Arguments for Limiting Editions

### 1. The limited edition in photography is inherited from artistic tradition!

The entire idea of the 'limited edition' is a concept borrowed from the world of fine-art print making. The 'original' was a plate or stone marked on, or carved by hand, by the artist. Marking on or into this printing surface (typically limestone, wood, or copper) the artist made a printing plate. The prints were then made from this one-of-a-kind plate, using the metal, stone or wood block as an ink delineator, not dissimilar to the way a modern-day rubber stamp is used to create an image. The process of applying the ink to the stone, wiping off the excess and/or applying the paper to the stone for printing, all done with repetition, eventually wore physical scratches in the image or degraded the carved edges. In short, the more prints that were squeezed and then pulled from the printing plate, the more the resulting image suffered from the effects of pressure, abrasion and friction. Editions were limited because the physical materials that created the image were themselves limited. Obviously, because this is a slow process of degradation that occurs incrementally with each successive print, the earliest copies in the sequence of prints were more likely to be 'pure'. Later copies would exhibit the degradations so much so that eventually the stone or wood block would have to be discarded as no longer usable. Since it was a one-of-a-kind original, this ended the edition with finality.

This is the historical context for two related ideas: the limited edition and the vintage print. In fine-art print making, the limited edition implied a scarcity that was medium-imposed and the vintage print was more valuable because it was the one least degraded. The world of fine-art photography has misappropriated these terms and introduced the 'limited edition photograph' in spite of the obvious misnomer and obfuscation. More recently, we've seen the blossoming of the market for the 'vintage photograph,' a supposed premium value if the photograph was printed near the same time that the negative was made.

First, let's be honest about the mechanical logistics in photography. There is no mechanical reason why the number of photographs should be limited. The obvious exceptions might be Polaroid originals, emulsion transfer images, or hand-colored images, but we are not addressing these media in this book. With these few exceptions, there is no limit to the number of copies that can be made from an original negative, transparency or even a hybrid negative, for example, a digital negative. When the light from an enlarger passes through the negative to make an exposure on photographic paper, there is no degradation to the negative. None. The mechanics of the process do not degrade the original; hence, there is no medium-imposed limit to the edition nor is there a medium-defined vintage print.

Limited editions in photography are, quite honestly, a fiction. There is a limit to the number of copies of a photograph only because someone decides to impose an arbitrary limit for some purpose.

Vintage prints are, to put it bluntly, a strategy to sell inferior images for a higher price. This may be a bit harsh, but it is true. There is simply no relationship whatsoever between the quality of a photograph and its first appearance. First is not always better, but better is always better! Of course, scarcity (as in short supply) is a factor in the pricing of most vintage prints. But, it is important here to distinguish between the use of the term vintage (out of date, meaning old, historic, from a time long past) and vintage (period, meaning produced near the time when it began), which might be yesterday, in the case of a contemporary photograph. The idea that print #1 is better or more valuable than print #100 is arbitrary and a valuation that is, in all likelihood, not based on image quality.

2. **Even negatives are subject to time. They can be scratched, lost, burnt or destroyed. Certainly, negatives are limited!**

True, but this argument seems to me as missing the much larger point. Regardless of whether or not the negative is limited, certainly the photographer is. We are mortal and time is short. You may quote me on this. Certainly the number of prints a photographer can make from their negative is finite, limited primarily by the amount of time they can spend doing photography or making repetitious copies of the same negative; limited ultimately because they are. Isn't this obvious? As Ansel Adams said: "Photographers fade faster than photographs." Why then make such a big deal out of the actual limited number of prints? All artwork is limited in the sense that the photographer will eventually be unable to create the art. The edition limiting that I am against is an artificial limitation that imposes a predetermined limit on the number of reproductions that will be made from a given negative.

3. **Limiting is a time-honored tradition, even in photography. Lots of photographers limit the number of prints they will make from a given negative!**

Why? If the image degraded with repetition, I could understand it. But, if the motivation to limit the number of copies is not mechanical, what is it?

*The photographer might just become bored with an image and not want to make any more copies of it.*

Then just stop, and be done with it. Why announce a predetermined limit?

*If there will be a limit to the number of prints anyway, why not announce it?*

Again, why would a photographer choose to do this? What value is there to a photographer to announce to the world that there will be a limit to the number of copies of an image?

*If there is going to be only a finite number of copies, it might be useful for the people who buy or collect an image to know there are a finite number of copies.*

Of course there are a finite number of copies. There are a finite number of grains of sand on the earth. Of what use is it?

*It's important and useful to know how limited the print edition is.*

Useful in what sense? Let me be specific: For whom is it useful? How is this useful, say, for the buyer? Be honest, why announce the limit? In fact, isn't it really only useful to the seller? Buyers may, of course, eventually become sellers. But, it's only the seller who benefits from the limit. Cut to the chase: imposed limits are artificially placed on photography for the benefit of the seller — read 'marketing'.

There is only one reason to limit the number of photographs made from a negative, and this is because we all know that artwork and photography are subject to the laws of economics, the most important of which is supply and demand. An edition is limited so as to limit the supply and push the price higher. There is no other reason to do it.

There is a myth believed by most artists that I must admit bothers me greatly. This myth is that artwork is not subject to the laws of economics. According to the train of thought, artwork is not supposed to be a commodity. It is supposedly somehow above the machinations of buying and selling that governs potatoes, T-shirts, oil or pork futures. It is holy, sacrosanct and, not to put too fine a point to it, different. Hogwash. Artwork is subject to the law of supply and demand just like any other commodity that is bought and sold.

Limiting the size of an edition is not an artistic question, it is a marketing strategy. Unless we can be honest with each other about this fundamental issue, we are simply fooling ourselves. And, there is nothing more sadly comical than a self-deluded artist. The argument usually is stated: "There is a limit; therefore, the price must go up." In fact, the truth of the strategy is just the opposite — we want the price to go up; therefore, we will impose a limit to facilitate justifying a higher price.

*Fine, but what is wrong with this? It's a free country and an artist (or gallery) is free to determine any marketing strategy they want. Why shouldn't they try to sell work for as much as they can?*

They should. But ultimately, I've seen this become unhealthy for photography and in particular for beginning and mid-career photographers. I say this for several reasons:

- The higher print prices rise, the fewer buyers there will be.
- This ultimately limits the market for photography to those few who can afford it.
- This breeds an elitism, which limits the market for new or mid-career photographers.
- Photography becomes judged by the signature on the work rather than the image itself.
- When sales galleries have to choose between dedicating an exhibition space to a newcomer (with, say, a $400 price) and a master photographer (with a $4,000 price), they choose the master for the obvious reasons.
- The more the established (and deceased) photographers dominate the gallery scene, the more repetitious become the exhibitions and publications. The audience gets bored and moves on.

I am not blaming galleries for this trend. If I were in their business shoes, I would probably follow their same path. It just seems to me that when a paradigm is employed that ultimately creates a smaller and smaller market with higher and higher prices, very few people can be involved in collecting and this cannot be healthy for photography. Photography is the quintessential democratic art form, both in making photographs and (theoretically) in collecting them. When a strategy (like limiting editions) interferes with this ideal, it has to be questioned.

*But some art buyers want to know that they own a piece of artwork exclusively, or almost exclusively. A limited edition is useful to them.*

An ego in the world of the art connoisseur is not wholly unknown. But why not buy sculpture or painting? If they love photography, let them collect in other ways. Let them commission work from a photographer with the stipulation that only one print will be made. Let them buy prints of deceased masters (where the limit is not artificially imposed). Let them seek out beautiful but rare images. There are alternatives that can satisfy their ego. But why should mid-career or even late-career photographers place limits on their own work? If they want to collect contemporary photographers, let them buy only print #1 of an unlimited edition.

*This is precisely the market known as vintage prints. Surely, they should sell for a higher price.*

Again, look at the historic model. In lithographs, the earlier in the print run, the cleaner and truer the printing plate. Vintage lithographs are more desirable because they are better, not because they are printed first. How does this relate to photography? Ask any photographer. Simply put, the best print is always the most recent one - never the first one. With repetition, a photographer become better and better at printing a negative. They learn as they go. Later prints are always more subtle, refined, finessed. In short, later prints are always better. There are only two exceptions to this and that is the occasional demise of a product, say a particular printing paper, or the aging of the photographer where eyesight, coordination or stamina begin to wane. Again, I'll say that later prints in photography are always better. If better is the criteria for vintage prints in lithography, why shouldn't it be the same in photography? Why aren't photographs that are printed later valued more?

I admit, I get tired of the game. Vintage prints in photography are supposedly worth more because they are rare and there are fewer of them. To whose advantage is this? The seller, of course. Again, it is a marketing ploy to prop up prices to unsuspecting (though not always naive) buyers.

Look at this another way: in lithography where the printing plate deteriorates, the later prints are the rare ones. Lots of plates simply give out and deteriorate. Using the logic from photography, these later prints would be worth more because they are so rare. Fortunately, collectors of lithographs understand the higher principle that quality counts for something even more important than scarcity.

So why all this emphasis on the rare photograph? Ask the snake oil salesman why his elixir is not made from common ingredients and you'll find the answer to this question. This 'induced scarcity' associated with both limited editions and vintage prints is a concept that has been capitalized on and abused by a common human emotion — greed. For example, it was reputed that Salvador Dali signed hundreds of sheets of blank paper shortly before his death so his printers and estate could continue to flood the market with original prints. Where there is will to defraud, there is a way.

Thus, as always, the government steps in to save us from ourselves. The states of New York, California, Illinois, Arkansas, Hawaii, and Maryland have laws protecting the consumer from the abuse of fraudulent misrepresentation of edition sizes and authenticity. For prints sold into these states with a value of at least $100 (less frame), the print must be accompanied by a certificate of authenticity that describes the name of the artist, the medium, when it was produced, the size of the edition, whether the print was signed, if it is estate signed (posthumous), a photo reproduction, if unsigned was it authorized by the artist or estate, etc. — in other words: a written guarantee.

## So what to do?

### The True Meaning of 'Edition'?

Dictionaries can sometimes be misleading because they define words as they are supposed to be used, not as they are used. I tend to discount arguments that rely on dictionary definitions to prove a point. This time, however, I think there is something to be gained from a consideration of the dictionary definition of the term edition. This is from my favorite dictionary, the Encarta World English Dictionary:

1. **Printed Version**, one version of a publication issued serially, periodically, or in multiple formats
2. **Broadcast Version**, a version or installment of a broadcast for a particular time or purpose
3. **Printed Batch**, a batch of identical copies of a publication all printed at the same time
4. **Batch of Items**, a batch or number of items all produced at the same time
5. **Similar Thing**, a version or copy of something

The term 'edition' developed from the Latin *edere* 'to give out,' and from *dare* 'to give', and there are so many lessons to take from this dictionary definition.

### Lesson 1

First, notice in the third definition referring to a printed batch the phrase 'printed at the same time'. I laugh. How many times have you seen a photograph marked 1/250 or 1/50? Do you actually believe the photographer made all those copies? Or do you instinctively know this is a theoretical limit only. I maintain that 99% of all photographs marked 1/50 never make it past print #5.

And don't you love the reference in the first definition to 'multiple formats'. Let's see now, if I do an 8x10 version and it should sell out completely, can I then do a 16x20 version with integrity? How about an 11x14 version? What about 10x13? Or 9x11? Is 8x10 okay? Just where do I cross the line of integrity? Will this line of integrity be the same for the photographer, the gallery owner and the collector who owns the sold-out 8x10 version?

What if I change the toner from selenium to brown toner? Is this now a new version, which I can reissue as a new edition with impunity? What if I change from Ilford to Forte printing paper? What if I change from silver-gelatin to photogravure or digital inkjet? Are these different editions? What if I crop the image to a panorama or a square? Am I violating a trust by reissuing a sold-out image with any of these changes?

And this is the core of the issue — trust. Nothing could devalue an artist's work faster than to violate the limit of an edition, except forgery. There is the recent controversy about Lewis Hines' work being printed posthumously by Walter Rosenbloom and offered as 'vintage prints' (see 'The Photo Review', edited by Stephen Perloff). Was this so controversial because they were fakes or because they, by sheer numbers, diluted the value of the original photographs? Or was it that these prints violated the trust between photographer and the collector, the gallery and the buyer?

The issue of limiting an edition of photographs is all about this trust. If there is anything sacred in the economic transaction it is this trust. You trust that the buyer will give you more money for your work, and they trust that you won't ever produce it again. Once this bargain is forged, it must not be broken. But if you box yourself into this corner, as an artist you are committing yourself to never again deepen your creative vision with this image. Doesn't this violate a trust you have with your creative self, your personal pursuit of excellence? If you are prevented from making it better when you know you can; prevented because you are contractually obligated to leave it inferior — haven't you sold out just a bit to the least common denominator of economics? Doesn't this violate a trust inherent with the artistic process?

There is another part of this that is even more bothersome. Once the edition is sold-out, who makes money on it then? If the artwork is viable in the art market, it is only the gallery, reseller or collector who can ever make money on the sale of that artwork once it can no longer be produced by the photographer. Does it make sense for the artist to limit their income this way, enabling others to profit while they are cut out of the economic equation? Limiting the size of the edition can only hurt the artist. If the artwork is not saleable, the size of the edition is non sequitur. If the image has market potential, a predetermined edition limit can only reduce the photographer's income. The only exception to this would be when the photographer can perfectly predict the market potential of an image. Enough said.

And, by the way, we all know that the price goes up dramatically once the edition is completely sold out or the photographer dies, right? There is an old (and somewhat sick) joke around art and photographic circles that says if you want to raise your prices, start a rumor that you've contracted a deadly and incurable disease. Geez.

Then, there is the issue of time, particularly of changing tastes and fashions. Limiting an image today limits it for all time, assuming the prerequisite integrity on the part of the photographer. What if an image, style, subject or vision develops a larger audience in a year or a decade from now? Fashions change. Demand does, too. How can it be successful to create a marketing and distribution scheme today that you must abide by twenty years from now? Thank God, we didn't do that with hair and clothing styles!

### Lesson 2

From the Latin edere, 'to give'. There are people (artists) who work only for themselves, caring nothing for the world at large or for an audience for their work. These are the sane artists, I think. The rest of us long to have our work seen. I have produced a lot of photographs in my art career, and I hope to create many more. When I am gone from this earth, I hope, I don't have a closet full of matted photographs, stored away in archival boxes with little tissues to keep them all pristine. They'd probably end up in a box on the front lawn in the garage sale for 25 cents each, where buyers would salivate over the chance to buy cheap mats for salvage. I would prefer to die artless — at least of my own work. I make photographs for others to enjoy, and I work hard at it only so they can fly away to homes other than mine. Collecting my own art seems a bit redundant.

I have often proposed a question to workshop students as follows: If a year from now, you had to look back on your photography career and assess the success of your artistic endeavors over the last twelve months, which would you prefer: That you had sold a few pieces of work for lots of money, or that you had lots of your images hanging in people's homes and offices, which they enjoyed every day, even if you had no money to show for it? It's amazing how many photographers unhesitatingly would prefer distribution over income. Of course having both would be perfect, but if the choice must be made, distribution seems the clear preference for most folks.

Then, why limit the edition? If virtue lies in sharing, why not strategize for maximum distribution rather than to maximize income? By the way, here is a hint: if you want to make a lot of money in life, being a photographic artist might not be your best first choice!

"But," you say, "I can't afford to give away all my artwork." Then don't. Give what you can. Sell it for what you must. Find another way. As an artist, you are a creative individual. Why not apply a portion of your creativity to developing an audience for your work that you can afford!

### One of One?

Have you ever considered producing only one print from a negative, marking it 1/1 and taping the cut or scratched negative to the back of the mount-board as proof? I have often been entertained discussing this idea with photographers and have been surprised how many of them have, at one time or another, contemplated this idea. I like this idea, even if I've never been able to convince myself to try it. I've never known anyone to have the commitment to do it either.

Why? When pressed, I hear photographers respond that they are afraid that they might just limit their best-ever image to that one copy or that they hope that someday they might learn a technique to print the image better. Either of these points of view demonstrates my ideas in practice. Marketing prevents the singular print. Knowledge renders the vintage print impotent.

Have you ever made a print from a negative, sold it and then subsequently learned how to print it better? Did you contact the buyer of the earlier version and offer to exchange their inferior version for the new, better one? If not, why not? Could it be that, as Ansel Adams stated so well, the negative is the score and the print is the performance? Like a performance, a print is a statement in time of your abilities, sensitivities, skill and artistic savvy.

To do editions of one, and only one, might be fun and challenging, but unless the physical materials dictate such a severe approach, this seems disingenuous and somewhat phony. Again, it's all marketing and ultimately self-defeating.

#### No Limits Whatsoever?

The most popular alternative to limits is the no-limit approach. I know many photographers who don't limit their images or even number them. I used to be one of these photographers — until I saw firsthand the effects of this strategy.

A number of years ago, I visited numerous people and galleries in the Carmel area, doing research for LensWork. In the course of my travels, I coincidentally happened to see six different prints of the same image, 'Horizontal Aspens' by Ansel Adams. The prints were different sizes, different papers, and different renditions. There was one version, however, that simply glowed. It wasn't simply better than the others — it toasted them. This clearly wasn't just another copy in a long edition run. It simply could not have been printed at the same time as the others. What was its history — to use the art world term — its provenance? Why was it different? Unknown, lost to history.

This experience set me to thinking about the context of history, personal development as an artist, the history of an image and the full development of the creative vision for an image. I realized that this is a process, not an event. And it is not just a process of the darkroom and of technical skill in printing. It is also a matter of artistic sensibilities and talent. As we grow as individuals, our artistic talent does too, hopefully! As time passes and our maturity deepens, so does our creative vision and talent. This is a part of our personal history and the history of our art. With this in mind, I have always disclosed full information on my fine-art photographs. For me, this started with a simple question: What date should one use on the surface of the print near the signature? The date of the negative, the date of the print or the copyright date? Just to avoid confusion, I list all information on a single sheet of paper that is affixed to the back of the mat board. Where I make images without limits, this information at least creates a personal provenance and brief history of the print.

### Alternatives

Having now taken full aim on the most popular paradigms and shot holes all over them, I suppose I now bear the responsibility to suggest a better solution. I can suggest one, but I hope my idea can be seen for what it is: my idea, not a definitive one for all times, all places or all people.

I have developed two ideas that seem to me to make sense, both from a mechanical/production point of view, as well as an economic one. My criteria in creating these strategies are rooted in the most important of all the ideas I've discussed in this chapter — trust. Any discussion of edition size must be able to stand the test of trust, both to the collector and to the artist. Edition numbering must also be truthful to the medium and based on honesty about the mechanical process, as well as the realities of the market. If it fails these criteria, it will be no better than the phony edition limits we see so often used in photography today — unfaithful to the medium, a perversion of the historical context, and merely a market game, whose intention is to defraud rather than clarify.

#### Numbering Only

The first idea is this: Do not limit the number of copies of a photograph, but do number them. This creates a sequential history for the image and allows collectors to know where, in the sequence, any particular version was created. This method is simple, easy to administer, and honest. It neither limits the image, nor ignores the importance of time in the production of the photograph, or in the maturing and creative vision of the photographic artist. Instead of '1/250,' why not just '#1'? To collectors this delineates the vintage print without denying the photographer the opportunity to refine his or her vision or execution of that negative.

### True Editioning

The second idea is better, albeit somewhat more detailed and involved. Follow the plan of the book publisher, using the ideas in the dictionary definitions above. Books are printed in a 'first edition', a 'second edition,' and so forth. Each edition is limited by the number of copies produced at that time. Also, a 'first edition' might undergo more than one printing: 'first edition, first printing' followed by a 'first edition, second printing', and so on. Each of the prints are also dated, and so, enumerated.

I see no reason why this paradigm cannot be adopted verbatim in photography. Begin with the creation of a 'first edition' with a defined and limited number of copies, printed all at once, dated and defined in time. Should this 'edition' sell out, it could be reprinted as a 'second printing', and so designated. Instead of a second printing, a variation in the image could be created with improvements in the execution and be called a 'second edition', again with a defined and limited number of copies, printed all at once, dated and defined in time. In fact, the first edition need not even sell out to create the second edition. Maybe the first rendition would be preferred by some collectors or buyers.

This strategy has the significant advantage of allowing the photographer an unlimited number of prints in their lifetime, allows for artistic growth in creative vision, which would be realized by the various editions, and at the same time, defines the work precisely for the collector/gallery who value such information. For example, in book printing a 'first edition' will often be more valuable than a later edition, even though the later one might be 'better,' that is, more durable, legible, and so on. The collector looks for the most valuable edition, the reader might look for the most functional, the decorator looks for the most handsomely bound.

Is this more cumbersome? Perhaps, but an even more important question is: Is it more honest? If the trust between buyer/collector and the artist is paramount, how could this be seen as anything but an improvement over the fuzzy '1/250' silliness that is now so prevalent in the photographic world? The key to implementing this strategy for your artwork lies not so much in the nomenclature as in the full disclosure of information and the force of your commitment to honesty and integrity.

Will the galleries like it? Probably not. Their economic interests are served too well by limited editions and the ease with which they can use the threat of a limit to motivate a hesitant buyer. Will the better galleries protest? I suspect not. They know that the more knowledge they can provide their buyer/collector, the better their relationship with that client. Don't forget, their relationships are also built on trust and honesty. Besides the best galleries understand their responsibility to the artist's economic well-being is just as important as their own. Galleries who don't think this way must consider artists disposable and replaceable, and I suspect these folks would make bad partners for your art career.

## Conclusion

I am sure that painters, sculptors and other artists will laugh at this idea of editions and the convolutions of this debate. But we are photographers and our chosen medium allows us to define ourselves differently. It is this freedom to define that also places on us a responsibility to think clearly about these issues and mold our career and our artwork in the best possible way. To deny the reproducibility of photography is to deny its very nature. To ignore the implication of artificially limiting the size of an edition is to be numb to the realities of our production.

I began this chapter by stating this issue is a thorny one. As you can see, there are no hard and fast answers to this issue, but that does not mean there are no hard and fast answers for individuals. Next time you are in the darkroom producing an image, how many will you make?

Brooks Jensen is a well-known fine-art photographer, specializing in small prints and hand-made artist's books that incorporate original photographs. He is also the co-founder and editor of LensWork, a bimonthly magazine on photography and the creative process. His articles, interviews, and books make Brooks one of fine-art photography's most influential innovators.

www.brooksjensenarts.com

This page intentionally left blank

# Part 2

# The Science

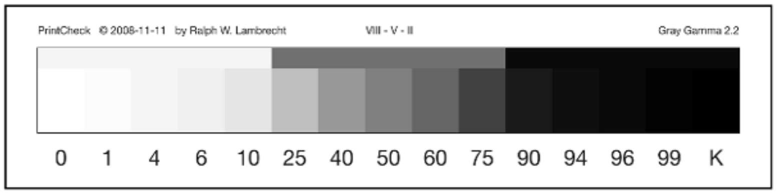
© 1998 by Ralph W. Lambrecht, all rights reserved

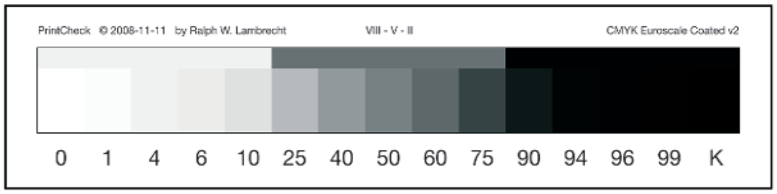
# Tone Reproduction

Silver-gelatin photographs are capable of rendering image tones from the brightest whites to the deepest blacks, but the image quality of every book is limited by the paper and inks used during its printing process. Selecting bright-white papers for offset printing is not a problem, but unfortunately, even the darkest printing inks cannot compete with the maximum blacks of a real silver-gelatin photograph.

Consequently, the resulting book images are always inferior to their photographic counterparts. This is not a huge problem with regular publications, but it is of great concern to us, because we do not want to lose any learning effort to the technical limitations of a mechanical printing process.

Since authors — as concerned with tonal accuracy as we are — should not leave the publisher and printer guessing at their intentions, we added two step tablets to this page, purely to support and control the printing process of this book. We hope that it helped to optimize the tonal accuracy on all pages and kindly ask you to excuse and ignore them here.


PrintCheck © 2008-11-11 by Ralph W. Lambrecht
VIII - V - II
Gray Gamma 2.2
0
1
4
6
10
25
40
50
60
75
90
94
96
99
K


PrintCheck © 2008-11-11 by Ralph W. Lambrecht
VIII - V - II
CMYK Euroscale Coated v2
0
1
4
6
10
25
40
50
60
75
90
94
96
99
K

This page intentionally left blank

# Introduction to the Zone System

## An overview to get you started

Have you ever looked at a scene and had a clear vision of the final print? Sometimes the image turns out just as we expected, but as often as not, the final print is far from what we intended. In the first half of the 20th century Ansel Adams and Fred Archer developed a system to replace the guesswork with much needed control over the photographic process. They called it the 'Zone System'.

For most serious fine-art photographers, whether amateur or professional, the Zone System continues to be accepted as a standard to control the entire monochrome tone-reproduction cycle from subject to print. The Zone System organizes the many decisions that go into exposing, developing and printing a negative, and once mastered, it provides a practical method to ensure maximum negative and print quality through the visualization of the final print and a thorough understanding of equipment and materials.

In brief, the Zone System works like this: The photographer decides how light or dark key elements in the scene should be in the final print and then takes reflective readings of these areas to determine exposure and contrast range. This is done to either obtain a literal recording of the scene or a creative departure from reality. The film is then exposed and developed to create a negative capable of producing the visualized print.

Several good books have already been written about the Zone System. Some are very technical, while others try to simplify the system to make it available to a larger audience. This chapter only provides an overview to assist in understanding what the Zone System is all about. How far you take it from here depends on your type of photography and your level of interest in photographic craftsmanship. However, a basic understanding of the Zone System is helpful, if not required, to get the most out of quality photographic publications, and it will increase your photographic confidence, even if you decide to continue to use ordinary exposure and development techniques.

### Zones

Good photographic paper is capable of showing bright white highlights, which transition smoothly to deep black shadows with an abundance of gray values in between. This continuous transition from bright white to deep black is divided by the Zone System into eleven zones, which are numbered with Roman numerals. Fig.1 shows the resulting zone scale. Zones II, III, V, VII and VIII are of the greatest interest, and consequently highlighted, but they all require some definition.

**Zone 0** is the darkest a photographic paper can get. It is the paper's black.

**Zone I** is almost black. In this zone, a hint of tonality is observed, but it has no pictorial value.

**Zone II** clearly differs from paper-black through signs of shadow texture, but the deep tones make it difficult to make out image details.

**Zone III** is as dark as textured shadows should get, otherwise important image details are lost.

**Zone IV** shows darker areas with full texture and detail.

**Zone V** is a fully textured middle gray, representing an 18% reflectance. The 'Kodak Gray Card' can be used as an exposure guide for this zone.

**Zone VI** shows lighter areas with full texture and detail.

**Zone VII** is as light as textured highlights should get, otherwise important image details are lost.

**Zone VIII** clearly differs from paper-white through signs of highlight texture, but the light tones make it difficult to make out image details.

**Zone IX** is almost white. In this zone, a hint of tonality is observed, but it has no pictorial value.

**Zone X** is as bright as the photographic paper's base. It is the paper's white.

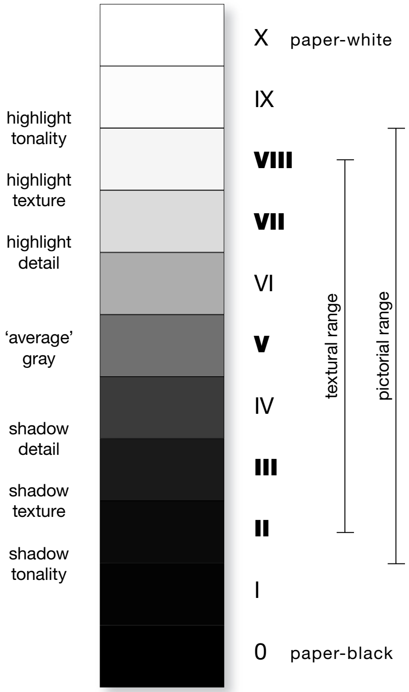


fig.1 In the Zone System, all gray values, from deep black to bright white, are divided into eleven zones, creating the zone scale.

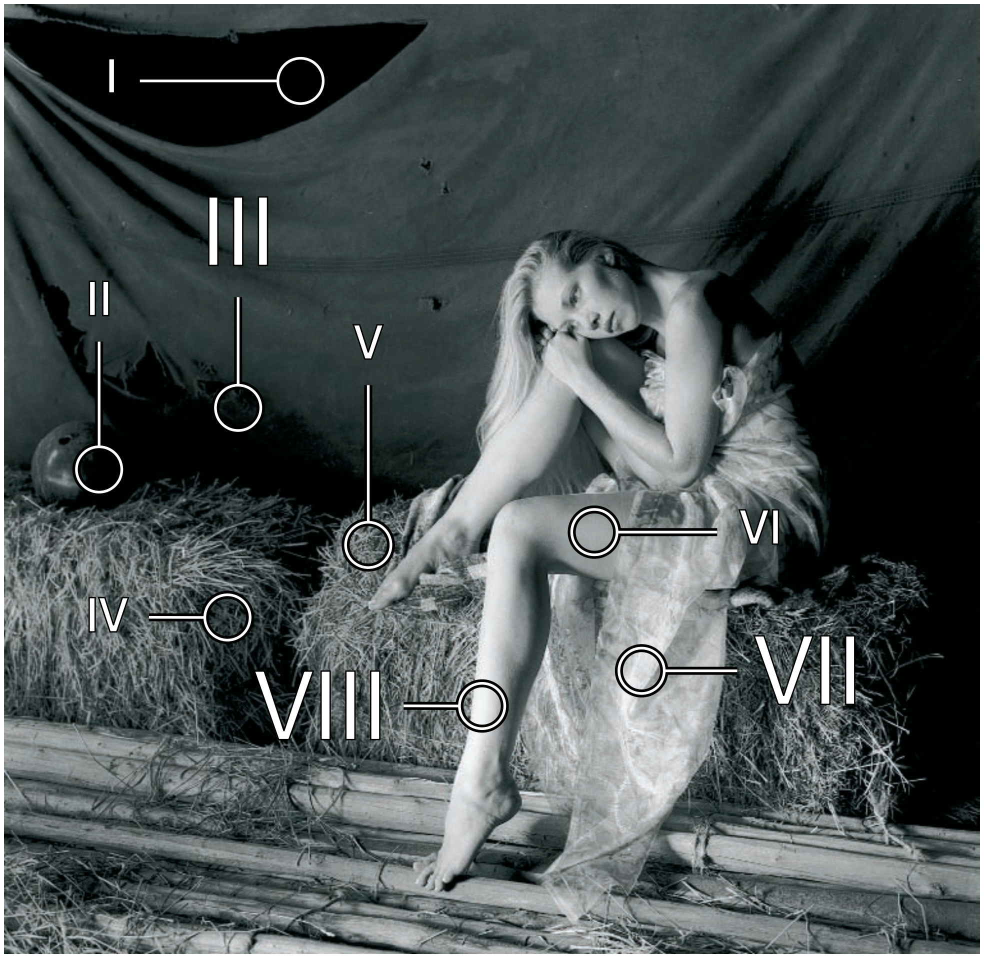
© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50012-0

The definitions above describe the zones in terms of tonal values as they appear in the photographic print. Nevertheless, it is important to be aware that zones are exactly one stop of exposure apart in the subject scene. Therefore, the lightmeter will find Zone III to be two stops darker than Zone V, and Zone VIII to be three stops brighter than Zone V.

## Visualization

This is the first step in the Zone System. Before the actual picture is taken, the scene is viewed with the final photograph in mind. The Zone System practitioner looks at the scene, identifies the areas of pictorial significance and forms a mental representation of the final photograph. The brightest highlight cannot be brighter than the paper's white, and the darkest shadow cannot be darker than the paper's black.

fig.2 During print visualization, textured shadows are thought of as being on Zone III, and textured highlights are envisioned to be on Zone VII or tonal highlights to be on Zone VIII. All remaining values fall onto their respective zones.



During this process, the zone scale in fig.1 is used as a reference. Textured shadows, which contain important image detail, are typically visualized to be on Zone III, and textured highlights are usually imagined to be on Zone VII. However, for image brilliance, highlight tonality is more important than highlight detail, and it is recommended to alternatively envision tonal highlights to be on Zone VIII. All remaining values fall onto their respective zones (fig.2). Some photographers find it advantageous to record the results of this mental process in some form.

To obtain a literal recording of the scene, zone placement depends on the tonal values of the subject, but for a creative departure from reality, zone placement is entirely up to the photographer. In order for this to work, film exposure and development must be carried out in a way that supports the visualization.

## Exposure and Development

The photographers of the 19th century were well aware of the basic influence of exposure and development on negative quality. They already knew that the shadow density of a negative is largely controlled by the exposure, whereas the highlight density depends more on the length of development time. These early photographers summed up their experience by creating the basic rule of photographic process control, 'expose for the shadows and develop for the highlights'. The Zone System is based on this advice while applying the principles of sensitometry, which were pioneered by Ferdinand Hurter and Vero Driffield in 1890. Nevertheless, only after the invention of reliable lightmeters did it become an accurately controllable system.

### Exposure

According to the axiom 'expose for the shadows and develop for the highlights', the Zone System practitioner begins by measuring the light reflected from the shadow area that contains the darkest important shadow detail, and places it on Zone III. This reading is then used to determine the film exposure.

Reflective light measurements are best accomplished with a specifically designed 1° spotmeter, but a 5° spot attachment for an already existing meter may serve as a substitute. Regardless of how the reading was taken, the shadow exposure recommended by any meter must be adjusted, since lightmeters are calibrated for the average gray of Zone V and not the relatively dark tones of Zone III. Without an adjustment, the measured subject area inevitably ends up on Zone V, and the shadows are rendered too light as a result. But knowing that, in the subject, Zone V is exactly two stops brighter than Zone III, a compensating exposure reduction of two stops is applied to render the textured shadows as visualized. Some meters, specifically designed for the Zone System, handle this exposure adjustment automatically by allowing the user to place a measurement directly onto any visualized Zone. It is important to note that the shadow reading alone controls film exposure!

### Contrast

To check the overall contrast range of the scene, a reflected light measurement is taken from a tonal highlight area of the highest pictorial significance. If it automatically falls onto the intended zone, the scene can be considered to be of 'normal' contrast. But not all lighting situations are 'normal'. In a low-contrast scene, such as a foggy morning landscape, the difference between shadows and highlights is less than normal. In a high-contrast scene, such as a sunny day at the beach, the difference is greater than normal.

Consider the following two examples. In the first, a low-contrast scene, the difference between textured shadows (III) and tonal highlights (VIII) measures as only four stops. The film is labeled as 'N+1', since the missing stop (8-3-4=+1) indicates that a negative-contrast increase is required to compensate for the low scene contrast. In the second example, a high-contrast scene, the difference between textured shadows (III) and tonal highlights (VIII) measures as seven stops. The film is labeled as 'N-2', since the extra two stops (8-3-7=-2) indicate that a negative-contrast decrease is required. It is important to note that the highlight reading alone determines film development!

### Development

The Zone System practitioner is now ready for the last portion of the axiom 'expose for the shadows and develop for the highlights'.

It is a fortunate fact that highlights and shadows respond differently to film developing chemicals. Highlights develop quickly and build up negative density at a fast pace. Shadows also develop quickly at first, but soon negative density becomes retarded. Leaving the film in the developer increases shadow

## The Digital Zone System

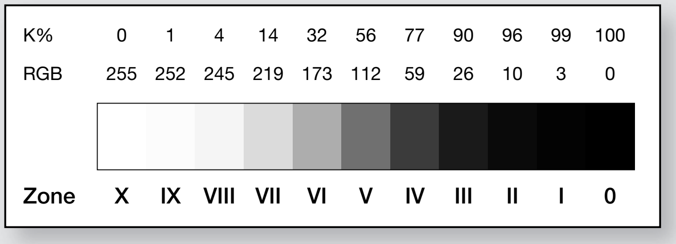
The advantages of controlling the tonal interpretation and reproduction of an image equally apply to images photographed, and printed, using digital equipment. The process of visualization remains the same, identifying key areas of the subject for reproduction in the print. However, the discussed axiom 'expose for the shadows and develop for the highlights' no longer applies. In fact, the opposite is true and with digital capture, in common with reversal film and photographic paper, the axiom simply changes to 'expose for the highlights and control the shadows with contrast'.

### Exposure

Unlike negative film, a digital camera is less tolerant to errors in highlight exposure and more forgiving with shadow exposure. It is very easy to overexpose highlight areas and reach the upper limit of a pixel value. Overexposed highlight are transformed into featureless whites. Shadow areas are less vulnerable, and although they can suffer from sensor noise, they can be manipulated to cajole extra shadow details out of seemingly featureless blacks. For these reasons, a good digital exposure ensures that Zone VIII and IX highlights are placed well within the pixel range. This is accomplished either by taking a reflected highlight reading and applying a controlled exposure increase, or by using an incident measurement of the main light source. At the same time, shadow detail does not deteriorate more than necessary.

### Contrast Control

Film contrast can be altered by the extent of its development. While it is possible to manipulate and increase the contrast of a digital image, the dynamic range of a digital camera's sensor is limited. This range is equivalent to reversal film and considerably less than color or B&W negative film. This may change with technological advances, but it is important to understand the limitations of digital capture and how they affect visualization. It is also worth noting that Ansel Adams was frustrated at the lack of development control with reversal films, which the Zone System requires. You may well experience the same frustration with digital cameras when it comes to normal and high contrast scenes.



| K% | 0 | 1 | 4 | 14 | 32 | 56 | 77 | 90 | 96 | 99 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RGB | 255 | 252 | 245 | 219 | 173 | 112 | 59 | 26 | 10 | 3 | 0 |
| Zone | X | IX | VIII | VII | VI | V | IV | III | II | I | 0 |

fig.3 A digital Zone System correlates monitor 'K' values (0-100%) and digital RGB values (0-255) to the eleven zones of the traditional Zone System.

density only moderately, but it increases highlight density significantly. This creates an opportunity.

A film exposed in a high-contrast lighting situation must be developed for less than the normal time to keep the highlights from becoming too dense to print. The reduced development time will affect the shadows to the point that exposure must be increased to prevent underexposed shadows.

A film exposed in a low-contrast lighting situation must be developed for more than the normal time to build enough density in the highlights. The increased development time will not affect the shadows significantly, but it will get the highlights dense enough for those 'brilliant' whites in the print.

## Zone System versus Automated Metering

The Zone System relies on the relatively laborious process of taking reflective light readings from key subject areas in the scene. Automated metering systems, built into modern cameras, take many readings within a fraction of a second. Even with the most sophisticated exposure metering systems now available, Zone System practitioners still prefer an external spotmeter in combination with print visualization to determine accurate film exposure and development, manually. They do so for good reason.

Simple, reflective lightmeters, as part of the built-in camera metering system, are calibrated with the assumption that each scene happens to be an average scene of 18% reflectance (Zone V). More advanced systems give the image center a higher importance, provide some exposure program settings based on different subject matter, or deploy a complex matrix metering system based on a huge database of image-taking experience. None of these assumptions are necessarily wrong, since the metering system does not actually 'see' the scene. However, for any scene that is not average, or does not closely match the program's assumptions, optimum film exposure cannot be achieved. Automatic metering is a blind approach.

fig.4 The two examples of 'Horse and Barn' with a white horse in front of a bright barn (top row, high-key image) and a black horse in front of a dark barn (bottom row, low-key image), can create a real challenge to any automated exposure system. Using such a system, both scenes are averaged, according to a pre-programmed algorithm, which typically represents the white horse too dark and the black horse too light. The Zone System, on the other hand, offers a practical opportunity to represent both scenes at their realistic tonal values.

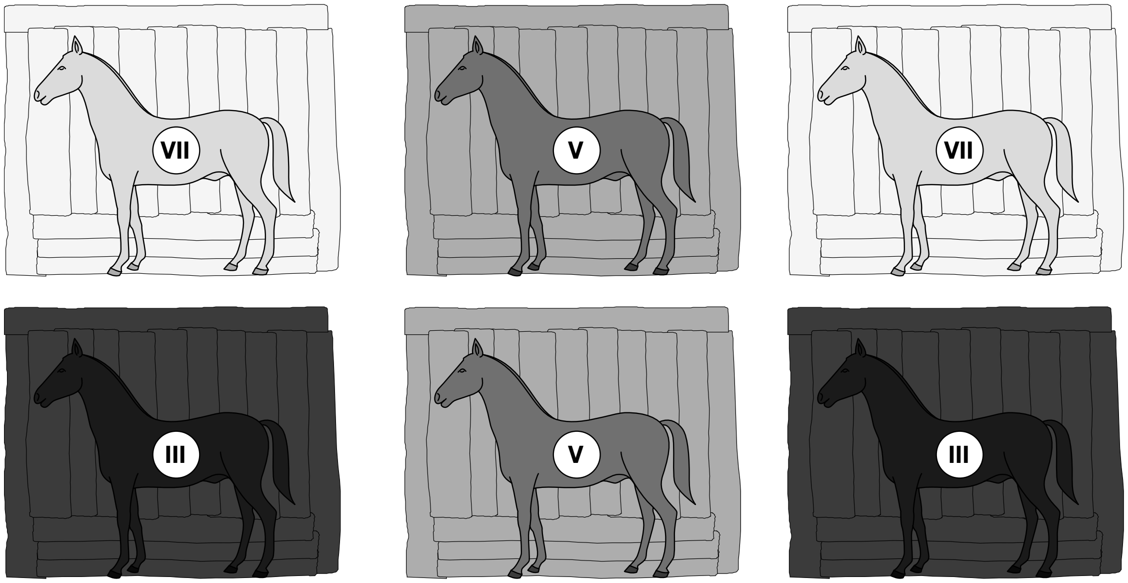


fig.4a **Exposure Extremes** Severe lighting conditions can easily fool even the most sophisticated lightmeters. Not actually being able to 'see' the scene, they need to make simplifying assumption.

fig.4b **Using Automated Metering** Lightmeters assume all scenes to be of average reflectance. This false assumption returns only average results, underexposing high-key and overexposing low-key scenes.

fig.4c **Using the Zone System** On the other hand, combining perceptual print visualization with lightmeter readings and the associated zone placement easily secures a literal recording of any scene.

In the Zone System, on the other hand, preprogrammed premises are replaced by viewing and interpreting the actual scene and taking individual measurements of key subject areas. The Zone System is a visual approach. The difference between automated exposure metering and the Zone System can be effectively explained using the high and low-key examples of 'Horse and Barn' (see fig.4).

Picture a white horse standing in front of a large bright barn (see fig.4a, top). In Zone System terms, the horse is on Zone VII. However, the camera's built-in meter cannot know that it is 'looking' at a white horse in front of a bright barn. It erroneously assumes this high-key scene to be a bright scene of average reflectance and will suggest an exposure setting to render horse and barn averaged around Zone V. This, unfortunately, underexposes the film by about two stops and will, consequently, create an image of a gray horse in front of a gray barn (see fig.4b, top), which is probably not the intention.

Now, picture a black horse standing in front of a large dark barn (see fig.4a, bottom). In Zone System terms, the horse is on Zone III. Nevertheless, the meter will assume this low-key scene to be a dark scene of average reflectance and will suggest an exposure setting to render horse and barn averaged around Zone V again. This time, the film will be overexposed by about two stops, which in effect creates an image identical to the previous: gray horse in front of a gray barn (see fig.4b, bottom).

An experienced Zone System practitioner handles these subjects differently. He or she looks at the scene and realizes that a black horse must be rendered as Zone III and a white horse as Zone VII in order to obtain a literal recording of the scene. A spotmeter reading of the horse is taken, knowing that the subsequent exposure always renders the horse as Zone V. This reading is then corrected to get a realistic image of the horse. Two stops of exposure are added (more exposure) for the scene with the white horse to move it from Zone V to VII (see fig.4c, top), and two stops are subtracted from the reading (less exposure) for the scene with the black horse to move it from Zone V to III (see fig.4c, bottom). This process is referred to as 'Zone Placement'.

A second spotmeter reading reveals that the bright and dark barn automatically fall onto Zone VIII and Zone IV, respectively, unless a development adjustment is made. Since this matches the visualization of the scene well, both frames will receive N (normal) development. The two scenes are high and low-key examples but are of normal contrast.

In fairness, it has to be said that an external incident lightmeter would handle the 'Horse and Barn' examples equally well as the Zone System. The characteristic white dome of the meter, pointed towards camera or light source, measures the light falling onto the subject rather than the light being reflected from the subject. The exposure suggestions are, consequently, independent from subject reflectance. Both scenes in fig.4 would receive the same correct exposure. As a matter of fact, using an incident meter gives the same result as measuring a Kodak Gray Card with a reflective meter. However, the incident meter is not capable of measuring the subject brightness range and, therefore, cannot be an ideal tool for Zone System work. Nevertheless, it is a perfect substitute in situations where speed is of the essence and subject illumination and contrast are more or less under control, as in model shoots.

This is the Zone System in a nutshell. It is a very flexible system, capable of handling any lighting situation, and I'll show you how to make it work for you in the following chapters.

# Introduction to Sensitometry

## A graph is worth a thousand pictures

Sensitometry is the science of measuring the sensitivity of photographic materials. It is commonly used to illustrate the characteristics of film and paper, whereby the image density is charted in relation to different amounts of exposure and the processing of these materials. The practical photographer has often little or no ambition to learn sensitometry, but a fundamental knowledge of this potentially complex technical field can be very helpful to understand how different films and papers respond to exposure and development variations (fig.1). This introduction will familiarize you with the basic terminology and introduce you to film and paper characteristic curves as they frequently appear in manufacturer's material specifications and photographic literature.

Ferdinand Hurter and Vero Driffield published their first characteristic curve in 1890 to explain how negative density and exposure are related. They charted the exposure in log units on the horizontal and the negative density on the vertical axis, to create what was later called the H&D curve in their honor. Eventually, this description went out of fashion and was first replaced by the term DlogE curve (density versus log exposure), which was later changed again to DlogH curve after internationally agreed ISO units were established. At the time of its introduction, most members of the photographic community did not readily accept Hurter and Driffield's method, but the manufacturers of film and paper soon saw the advantages. And some corporate research teams, such as Loyd Jones and his associates at Kodak, made huge contributions to the development and application of sensitometry, all based on Hurter and Driffield's pioneering work.

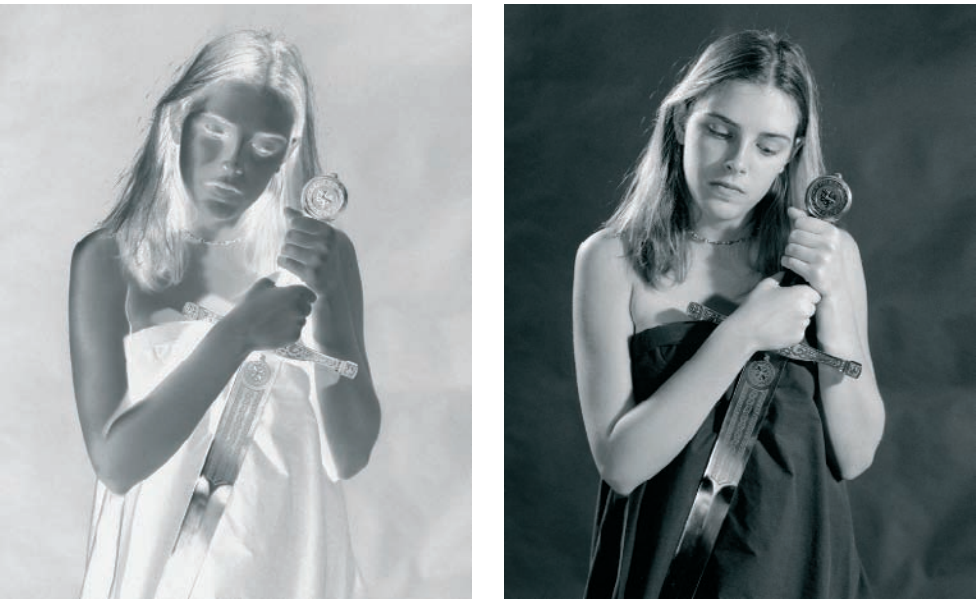


fig.1 The practical photographer is usually not interested in sensitometry, but it does reveal how films and papers respond to exposure and development.

### Characteristic Curves

Figures 2 and 3 show a typical characteristic curve for film and paper, respectively. Both curves are nonlinear, which simply means that a constant exposure increase does not necessarily produce a constant density increase. Initial exposure increases exhibit a relatively small increase in density and create a curve shape referred to as the 'toe'. Further increases in exposure create an almost constant increase in image density in the linear 'midsection'. Approaching maximum density, exposure increases have less and less of an effect, and the densities level off in the 'shoulder'. Adding exposure after Dmax has been reached will actually reduce density again, which is referred to as solarization, but only the region of the curve from toe to shoulder is of primary interest to practical photography.

Typically, papers are less linear than films are. This is more apparent as paper contrast increases, and it is also highly dependent on material differences. You may find papers with long or pronounced toes and small or short shoulders, favoring highlight

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50013-2

separation, or others with short toes and pronounced shoulders, favoring shadow separation. Similar differences can be found from one film to another, and film characteristic is significantly influenced by the choice of developer. Some film/developer combinations create a substantial film shoulder, compressing image highlights, while others create a long toe, compressing the shadows.

Using sensitometry to search for the ultimate film, paper or developer in general is futile. The best material is always the one that is best suited for a particular application. However, finding for example the film least sensitive to overexposure, the developer most forgiving to process errors, or the most complementary paper for a specific film is quite possible with even a basic understanding of sensitometry.

## Exposure and Density

Some photographers are unfamiliar with reading exposure in log units, as used in the horizontal axis of figures 2 and 3. However, they are likely to know that increasing or decreasing the exposure by a ‘stop’ multiplies or divides the exposure by a factor of 2. Using stops proved so useful that the industry applied the factor 2 to all exposure modifying variables as a basic increment. There is a 1-stop difference between the familiar numbers of the aperture (f/stop) scale, the shutter speed sequences on your camera, the main ISO film speeds (50/18°, 100/21°, 200/24°, 400/27°, ...), full EV numbers and even the subject zones in the Zone System.

In technical literature, it is more common to use a logarithmic scale instead. Even so, it is very easy to convert from one to the other. The logarithmic equivalent of the number 2 is nearly 0.3. This means that increasing the exposure by a stop is the same as adding 0.3 log exposure. Two stops equal 0.6 log, three stops equal 0.9 and so on. A log exposure change of 3.0 simply refers to a change of 10 stops. Just divide the log exposure by 0.3, and the result will be the exposure in stops. It’s that simple.

So far, we have only concerned ourselves with the horizontal axis of the characteristic curve responsible for the exposure. The vertical axis shows us how film and paper emulsions react to different exposures due to development. The most obvious material reaction to increased exposure is an increase in density. In the case of film, we refer to it as transmission density, and in the case of paper, we refer to it as reflection density. When charting characteristic curves, it is useful that density is the logarithmic equivalent of transmission and reflection, allowing us to keep the horizontal and vertical axis at the same scale.

A film with an absolute transmission density of zero does not exist, because this would mean that the film is 100% transparent. Every film has some inherent density that is material dependent but not related to exposure. Modern films have a gelatin emulsion on an acetate or polyester base that transmits about 80% of the light after processing. Consequently, they have an inherent density of about 0.1. Subtracting this inherent density of base and emulsion leaves us with the relative transmission density of the negative, which is a true measure of the film’s response to exposure and development. If, due to exposure and development, the density increases to the point where only 50% of the light is transmitted, then the transmission density has risen to 0.3. Every time a further density increase of 0.3 can be measured, the transmission is halved again. A transmission density of 0.6 transmits 25% of the light, 0.9 transmits 12.5% and so on. A practical limit for the relative transmission density of a negative is about 1.5, which is enough to record about a 10-stop difference in exposure (fig.2).

A paper with an absolute reflection density of zero does not exist either, because this would mean that 100% of the light reaching it would be reflected. The white base of most modern

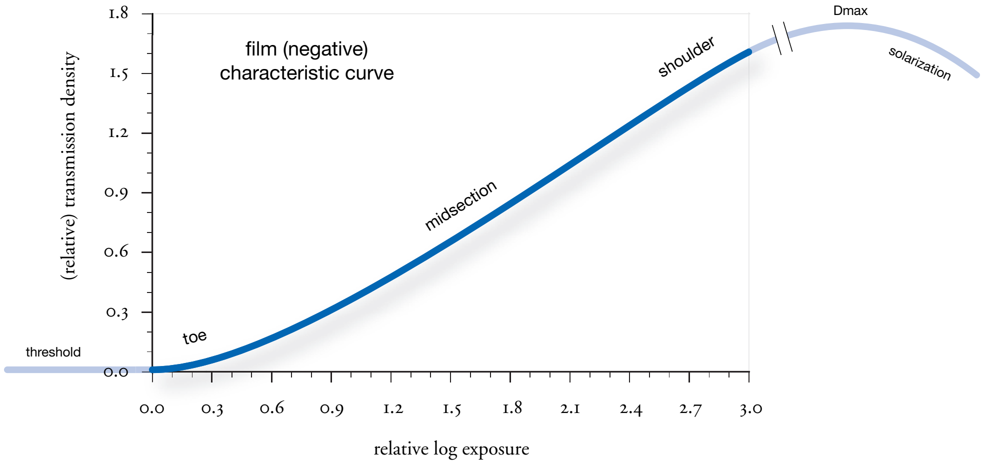
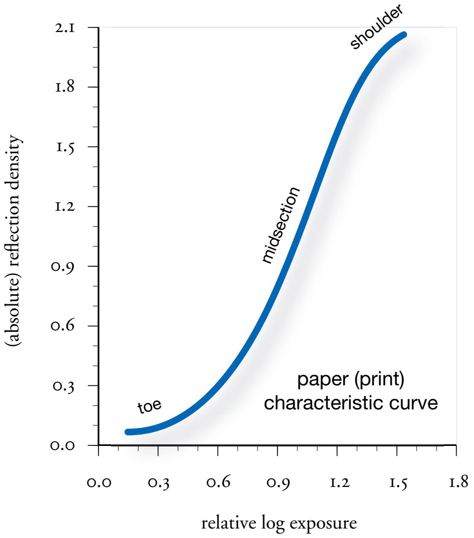


fig.2 This is a typical film (negative) characteristic curve, illustrating the nonlinear relationship between relative transmission density and exposure. Only the region from toe to shoulder is of primary interest to practical photography.

fig.3 This typical paper characteristic curve illustrates the relationship between absolute reflection density and exposure from toe to shoulder.



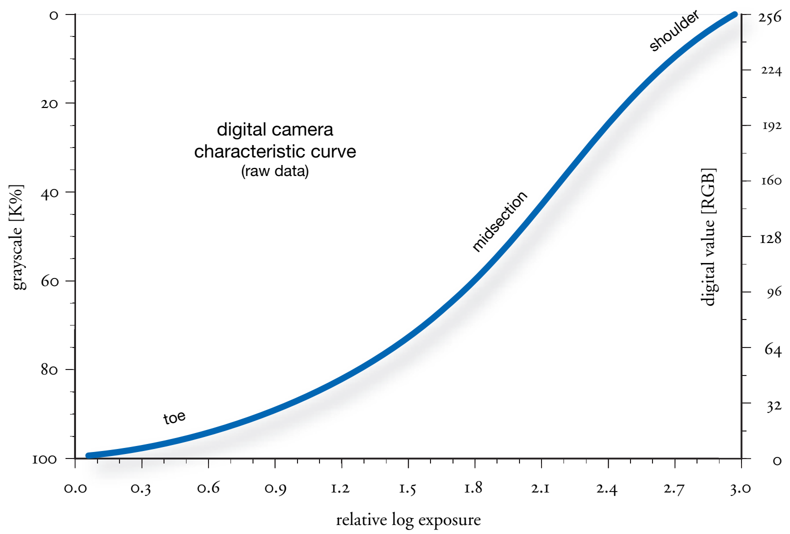


fig.4 This is a typical characteristic curve of a digital camera after the raw color image has been changed to grayscale. Similar to analog positive film, where more exposure means less density, grayscale values of the digital image (K%) decrease with exposure. Internally stored digital RGB values, on the other hand, increase with exposure.

photographic papers reflects about 90% of the light, and therefore, they have a minimum reflection density of about 0.05. A reflection density of 0.3 reflects 50% of the light, 0.6 reflects 25% and so on. Maximum densities of modern papers are about 2.1 and above, in which case the paper reflects less than 1% of the light that reaches it (see fig.3). Some toners increase maximum paper densities even further. However, reflection densities above 1.9 are of limited use to practical photography, because the human eye has difficulty differentiating darker tones under normal lighting conditions.

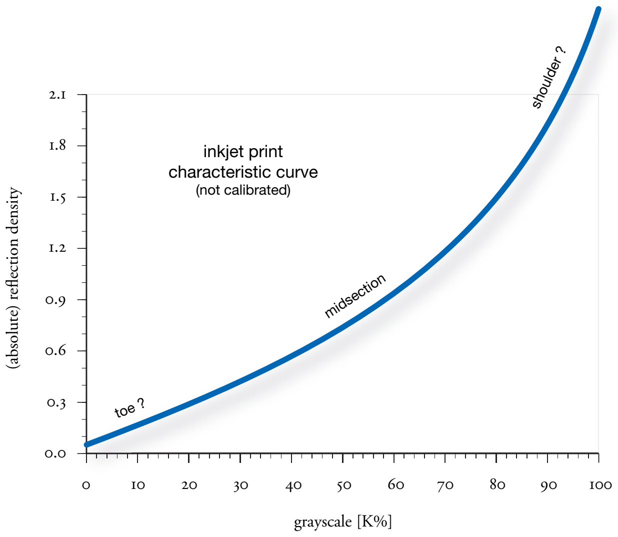


fig.5 The characteristic curve of an inkjet printer illustrates the relationship between the print's relative reflection density and the grayscale values of the digital image. This typical curve no longer has the distinctive toe and shoulder areas of an analog silver print.

## Digital Sensitometry

The principles of sensitometry can be equally applied to digital imaging. A digital camera converts light into digital numbers, which can be interpreted by computers and printers. Digital image-recording equipment is designed to work primarily with color images. Different colors and light intensities are recorded, using an additive color system in which three numbers define the red (R), green (G) and blue (B) content of every image point. The RGB color model allows us to distinguish between millions of colors.

In the case of monochrome photography, only the intensity of the light is important, and it can be represented by a single number. A typical grayscale image may have 256 distinct levels of gray (8 bit) or many more (10, 12 or 16 bit). The number of gray levels does not change the range of intensity, only the fineness of the tonal gradation. As the grays of a film negative are measured in density, the digital grayscale file is similarly measured in K%. The term 'K' is historically a measure of image density in terms of black ink, used during the printing process.

Figures 4 and 5 show the typical characteristic curves of a digital camera and an inkjet printer, respectively. Both curves are nonlinear but in a different way to film and photographic paper. Although digital camera sensors have a linear response, recorded numbers are modified, using a transfer function, before saving them to memory. This redistributes the tonal values more usefully across the scale. As with film and paper, each camera and printer model produces a different tonal distribution. Calibrated equipment, on the other hand, delivers remarkably consistent image characteristic. The unique benefit of digital imaging is, undoubtedly, that one can modify every aspect of the digital file before committing it to paper.

A solid understanding of sensitometry is not at all necessary when it comes to good photography from the viewpoint of creativity, composition, interest and impact. Nevertheless, sensitometry covers the underlying image-making principles and what happens fundamentally to film, paper or digital files from the moment of exposure. The real value of understanding basic sensitometry to the practical photographer lies not in knowing more about the scientific aspects of photography, but in having more knowledgeable control over the entire image-making process, which eliminates guesswork and increases efficiency and confidence.

# Tone Reproduction

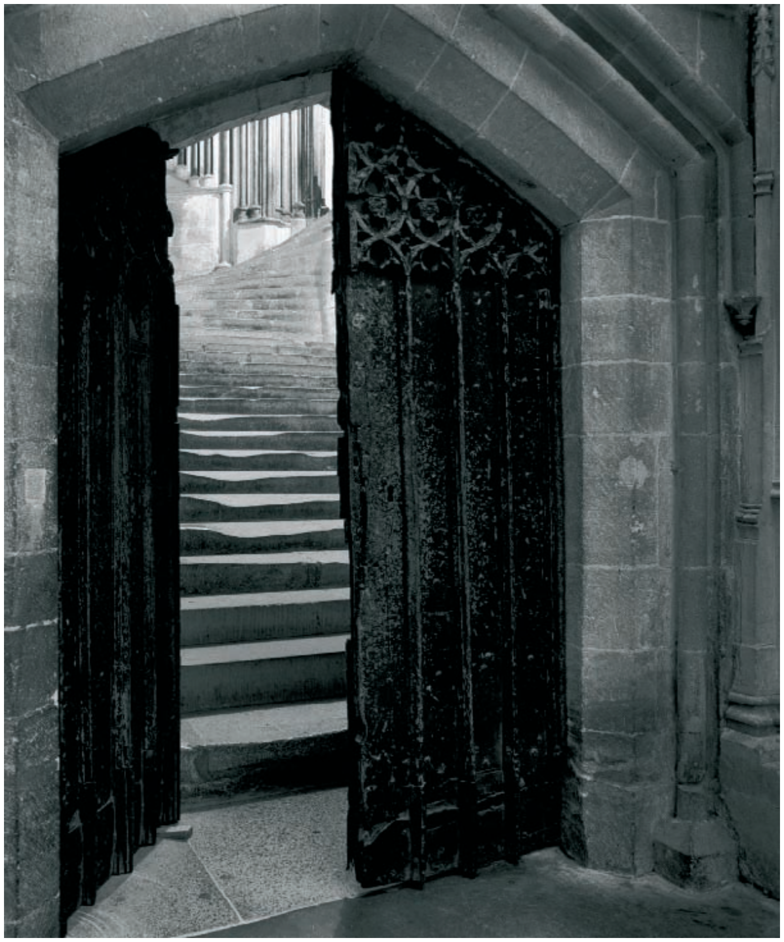
## Zone System and sensitometry combined

We have gained a basic understanding of the Zone System and sensitometry in the previous two chapters. Combining the two will allow us to get control over image contrast and understand how zones are represented throughout the image reproduction cycle. Ultimately, they show us the importance of tonal gradation and how to manipulate it through exposure, development, and critical material selection.

Studies conducted by several authors, including my own, indicate that most viewers prefer prints with a full tonal scale from pure white to solid black and an abundance of gray tones in between. Therefore, a widely accepted print is likely to have maximum contrast and full gradation. I'm not saying that a fine print requires all tones all the time, but most people like it that way, most of the time. Apart from the creative license of the artist, we generally like our printed images to be a reasonably true representation of the scene captured. Unfortunately, in many cases this is impossible, since the average subject brightness ratio is far greater than the maximum print brightness ratio. As a consequence, the resulting print is often a disappointing record that fails to satisfy our memory's expectations.

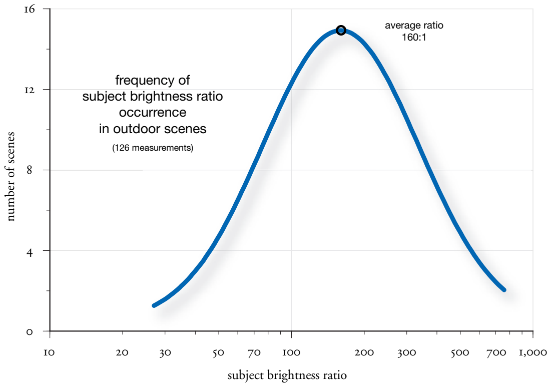
The most efficient man-made reflectors cast back as much as 98% of the light that reaches them, but natural objects are limited to about 90% reflection. On the other hand, nature's best absorbers reflect as little as 1.5% of the light that they receive. If uniformly illuminated, the maximum reflectance ratio of an outdoor scene is, therefore, about 60:1 (90/1.5) or 6 stops. Although these extremes are not unlikely, average outdoor scenes have more moderate reflection ratios of around 30:1 or about 5 stops.

So far, we have assumed perfectly diffuse lighting, but the various objects in an outdoor scene rarely receive the same illumination. The subject lighting ratio between direct light and shadow illumination can be controlled in a studio environment, but in natural daylight, it can reach values of up to 12:1 on a clear sunny day. This can significantly alter the subject brightness ratio. Let's assume that we have a very dark and a very bright object placed in a sunlit scene. If the bright object is moved into the sunlight and the



© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50014-4

fig.1 The measurements taken by Jones and Condit in 1941 serve as a starting point for an objective tone-reproduction analysis. They obtained data on the subject brightness ratio of 126 outdoor scenes. The lowest-contrast scene had a value of 27:1, and the highest-contrast scene had a value of 760:1. For the whole group of scenes, the average subject brightness ratio was 160:1.



dark object into the shade, then the subject brightness ratio is maximized to 720:1 (60x12) or almost 10 stops. These numbers were verified in a field study published in November 1941 by Loyd A. Jones and H. R. Condit, who analyzed data from 126 different outdoor scenes in which the subject brightness ratios ranged from a low 27:1 (about 5 stops) to a high 760:1 (almost 10 stops), averaging at 160:1 or a little more than 7 stops (fig.1).

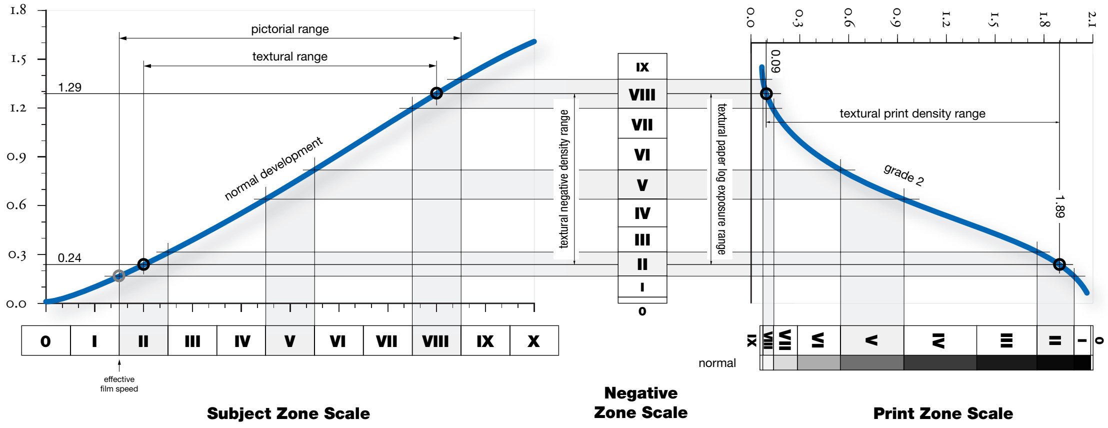
The greatest possible print brightness ratio on the other hand, is limited by the reflection density ratio of the paper. The white base of unexposed but fully fixed photographic paper is capable of reflecting about 90% of the light. A fully exposed and developed paper with a glossy finish can be so dark that less than 1% of the incident light is reflected. However, the extreme toe and shoulder regions of the characteristic curve are of little use to pictorial photography, due to the tonal compression they cause, and hence, the useful print brightness ratio is reduced to about 80:1.

Comparing this with the field test, it is evident that the paper is unable to realistically represent an average outdoor scene, by about a factor of 2 or roughly a stop. The next example can help us visualize how the paper is falling short of our expectations. We know from the 'Introduction to the Zone System' that Zone V has a reflectance of 18%. Zone VI is twice as bright in the subject zone scale, and therefore, it must have a reflectance of 36%. Consequently, Zone VII has 72% reflectance and Zone VIII must have twice that. But wait a minute! We said that the paper cannot reflect more than 90% and this calculation would get us above 100%. Besides, we are still missing Zone IX and X. The answer can only be that we do not have a linear relationship between subject zone brightness and print zone reflections. Photographic paper cannot handle the brightness ratio of an average outdoor scene. Zone V can be represented realistically at about 18% reflection, but the extreme zones must be compressed to fit into the print zone scale. This is why it is so challenging to capture the sparkle we remember from the original scene. Many printers labor with dodging and burning tools to bring some of the sparkle back. The Zone System does not eliminate these techniques, but it maximizes image contrast control and, therefore, actually promotes dodging and burning from being a poor rescue attempt to a powerful tool of creative print manipulation.

## Film and Paper Are Setting the Tone

Tone reproduction is one of the most important factors in print quality. Fig.2 shows how the tonal values transfer through the image reproduction cycle from

fig.2 During tone reproduction zones are transferred from the subject, through the negative, to the paper. The even zone spacing of the subject zone scale is altered throughout the cycle. The extreme zones are typically compressed while medium zones are often expanded. In the darkroom, the negative is projected onto the paper, and the textural negative density range becomes the textural paper log exposure range. The paper curve is turned sideways to accommodate this fact in this example of a film with normal development printed onto normal graded paper. The gray reference scale will be used in the rest of the book to identify tonal alterations due to material and processing modifications.



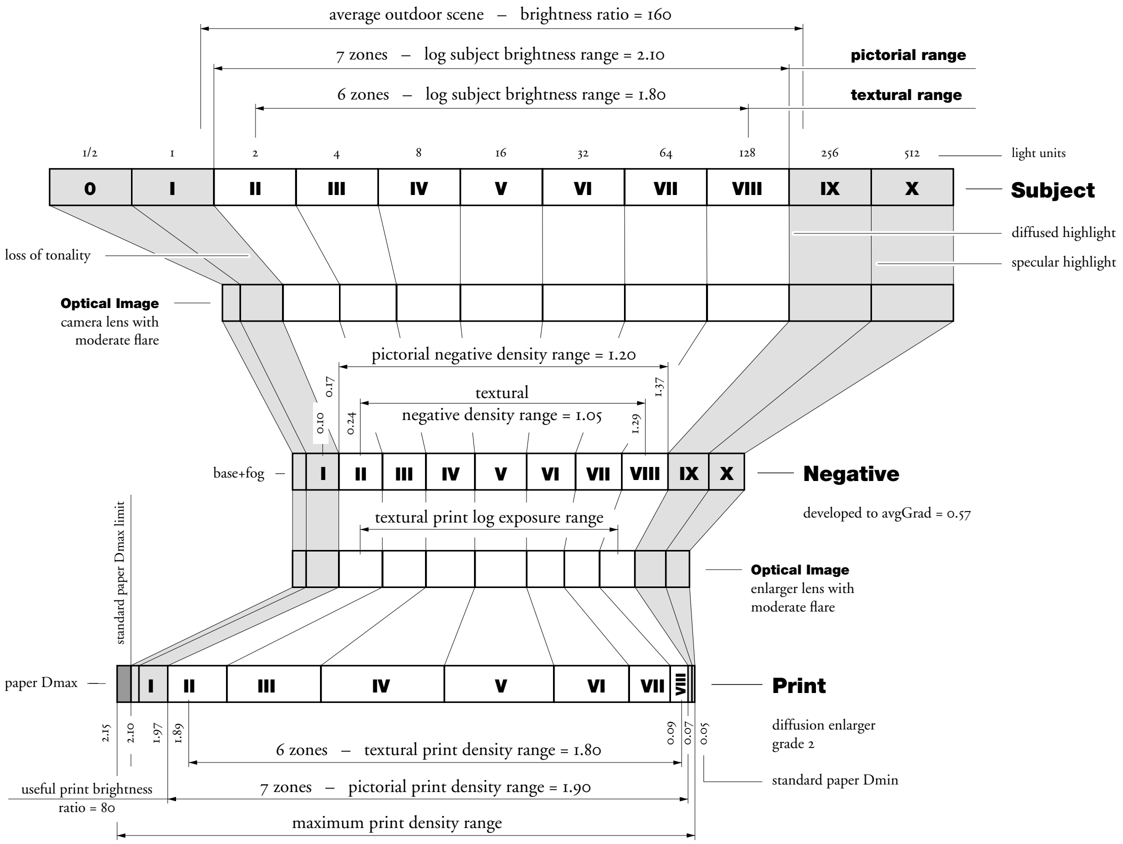

average outdoor scene – brightness ratio = 160
7 zones – log subject brightness range = 2.10
pictorial range
6 zones – log subject brightness range = 1.80
textural range
1/2
1
2
4
8
16
32
64
128
256
512
light units
0
I
II
III
IV
V
VI
VII
VIII
IX
X
Subject
diffused highlight
specular highlight
loss of tonality
Optical Image
camera lens with moderate flare
pictorial negative density range = 1.20
textural negative density range = 1.05
0.10
0.17
0.24
1.29
1.37
base+fog
Negative
developed to avgGrad = 0.57
textural print log exposure range
Optical Image
enlarger lens with moderate flare
standard paper Dmax limit
paper Dmax
Print
diffusion enlarger grade 2
2.15
2.10
1.97
1.89
0.09
0.07
0.05
6 zones – textural print density range = 1.80
7 zones – pictorial print density range = 1.90
standard paper Dmin
useful print brightness ratio = 80
maximum print density range

fig.3 This diagram, based on a Kodak original, shows how the zones are compressed and expanded in the tone-reproduction cycle from the scene to the final print. It also shows the influence of the optical images on tonal values, and it helps to standardize a few key terms and values for negative and print density.

the subject, through the negative, to the print, while creating their individual zone scales. This example explores the influence of film and paper, but it ignores any optical or physical equipment influence from camera or enlarger. Assumed is a negative, which was exposed and developed as normal and then printed onto a grade-2 paper. Ansel Adams supposedly abandoned the terminology of zone scales for negative and print in his later years, because he felt that zone scales are only applicable to the subject brightness range, turning into tonal scales for negative and print. Nevertheless, we will maintain the zone scales throughout the reproduction cycle in this book. It is consistent, and it helps to understand how zones are represented in negative and print, and how different materials influence them.

Zones II, VIII and V are highlighted, because they are considered to be the boundaries and the center of the pictorial range, respectively. All zones start out evenly spaced, exactly one stop apart in the subject zone scale. After exposure and development of the film, they are represented in the negative zone scale. Most modern films have a relatively straight characteristic curve except for the toe and the extreme areas of the shoulder. Therefore, severe tonal compression is restrained to the extreme shadow and highlight zones. All other zones in the negative are also compressed, but more or less evenly spaced. In the darkroom, the negative is projected onto the paper, and the different negative densities correlate to different print exposures. In other words, the textural negative density range becomes the textural paper log exposure range. In fig.2, the paper curve is turned sideways to accommodate this fact.

Throughout the book, the term ‘subject brightness range’ is used to describe a range of measurable light intensities. Strictly speaking, this is not correct, because brightness only refers to the human perception of luminance and not the measurable quantity of it. The term ‘subject luminance range’ is technically more accurate, but it is not frequently used in photographic literature. To avoid confusion, we have chosen to use the incorrect, but more generally understood, term and its abbreviation, SBR, instead.

| Zone | Negative | Print | Monitor |
|---|---|---|---|
| **0** | **0.00** | **2.10** | **100%** |
| • | 0.03 | 2.09 | |
| •• | 0.07 | 2.06 | |
| **I** | **0.10** | **2.04** | **99** |
| • | 0.14 | 2.00 | 98 |
| •• | 0.19 | 1.95 | 97 |
| **II** | **0.24** | **1.89** | **96** |
| • | 0.28 | 1.81 | 95 |
| •• | 0.33 | 1.72 | 93 |
| **III** | **0.38** | **1.61** | **90** |
| • | 0.43 | 1.48 | 86 |
| •• | 0.49 | 1.34 | 82 |
| **IV** | **0.54** | **1.19** | **77** |
| • | 0.60 | 1.04 | 71 |
| •• | 0.66 | 0.89 | 64 |
| **V** | **0.72** | **0.75** | **56** |
| • | 0.78 | 0.62 | 48 |
| •• | 0.84 | 0.50 | 40 |
| **VI** | **0.90** | **0.40** | **32** |
| • | 0.97 | 0.32 | 25 |
| •• | 1.03 | 0.25 | 19 |
| **VII** | **1.10** | **0.19** | **14** |
| • | 1.16 | 0.15 | 10 |
| •• | 1.22 | 0.12 | 6 |
| **VIII** | **1.29** | **0.09** | **4** |
| • | 1.35 | 0.08 | 3 |
| •• | 1.42 | 0.07 | 2 |
| **IX** | **1.48** | **0.06** | **1** |
| • | 1.55 | 0.05 | 0 |
| •• | 1.61 | | |
| **X** | **1.67** | | |
| • | 1.73 | | |
| •• | 1.79 | | |
| **XI** | **1.85** | | |

© 2000 - 2006 Ralph W. Lambrecht

fig.4 This table shows standard Zone System values for relative negative transmission and absolute print reflection density in 1/3-stop increments. To illustrate the relationship between the analog and the digital Zone System, typical grayscale values for computer monitors are also shown in K%.

Zone spacing changes again as soon as the negative is printed, which is represented through the paper characteristic curve. The already compressed highlights are 'hitting' the pronounced toe of the paper curve, where they are compressed even further, making highlight separation difficult. Quite the opposite is happening at the center of the zone scale. Zone V is falling onto the steep portion of the paper curve, and it is being expanded as a result, causing increased tonal separation in the midtones. At Zone II, the process is reversed into tonal compression again, due to the influence of the film toe and paper shoulder.

The actual tonal representation depends on the film, developer, paper, and to some extent even on the equipment used. It may also differ somewhat from the simulation in fig.2. Nevertheless, the fact that zones are being compressed and expanded, while moving through the reproduction cycle, is realistically presented. Approximating gray tones were added to fig.2 in order to provide a visual relationship for the print zones. This normal tonal scale will be used as a reference throughout the rest of the book, showing how any material or processing change will alter the tonal representation.

## Tone Reproduction and the Zone System

Fig.3 also illustrates how the zones are compressed and expanded in the photographic reproduction cycle from the scene to the final print. The difference to fig.2 is that the characteristic curves are not shown anymore, but in addition to their contribution, the influence of the optical images from camera and enlarger are explored. Moreover, a few key values for negative and print density are labeled so we can start to create a personal density standard, which will function as a reference for your own values.

Fig.3 presents the evenly spaced subject zones with their doubling light units on top. The average outdoor scene, with a subject brightness ratio of 160:1, is equivalent to about 7 1/3 stops. It will be of more interest, and much simpler, for us to follow the 7 stops of the pictorial range, from the beginning of Zone II to the end of Zone VIII, through the tone reproduction. We will, therefore, ignore the remaining 1/6 stops on either end of the average outdoor scene. They fall within Zone I and IX and have little tonal value anyway. In addition to the density values of the pictorial range, it will prove useful to also track the textural range, which reaches from the center of Zone II to the center of Zone VIII. But for now, let's keep in mind that we are starting with seven zones, or a subject brightness range of log 2.1.

Zone compression starts as soon as the lens has formed the optical image in the camera. Minute lens and camera flare, caused mainly by the higher zones, bring non-image forming light to the lower zones. Consequently, the zone scale moves to the right, compressing the lower zones and leaving the higher zones unaffected. The resulting image is projected onto the film and is turned into negative densities through development and processing. A typical film characteristic curve has a relatively low gradient, which compresses all zones evenly, except for the toe and shoulder, where the low and high zones are compressed more severely. A quality negative, suitable for a diffusion enlarger, has a negative density range of about log 1.2 to cover the seven zones. This is little more than half of the original subject brightness range.

Zone compression continues in the enlarger. Similar to the light distribution in cameras, enlargers and their lenses suffer from flare too. However, since image tones are reversed in the negative, the more luminous lower zones now scatter some non-image forming light into the higher zones. As a consequence, the zone scale moves to the left, this time compressing the higher zones and leaving the lower zones unaffected. After image projection and paper processing, we can evaluate the final print. Photographic paper, by design, has a much larger density range than the negative, which provides an opportunity to expand the zones again. Nevertheless, toe and shoulder of the paper characteristic curve compress the already compacted shadow and highlight zones one more time, but midtones are expanded again and often exaggerated.

In the end, the compression from the subject brightness range to the negative density range, and the subsequent compression and expansion to the print density range, have shifted the evenly spaced zones of the subject significantly. As a rule of thumb, low and high zones are usually compressed and middle zones are typically expanded. There is little similarity left between the original subject zone scale and the final print zone scale. With modern papers, a pictorial print density range of log 1.9 is typically available to cover the original seven subject zones. This almost brings back the original subject brightness range of log 2.1. However, we must realize that the original brightness ratio is significantly reduced, from 160:1 in the subject down to about 80:1 in the print. We have to accept this material behavior to some extent, but throughout this book, we will discover ways to work around it or manipulate some of it to our advantage.

## Standard Values and Their Manipulation

The table in fig.4 shows a collection of standard Zone System values for relative negative transmission and absolute print reflection density in 1/3-stop increments. To illustrate the relationship between analog and digital Zone System, typical grayscale values for computer monitors are also shown in K%. The development of these numbers was based on a few material and equipment assumptions, and they may not be completely valid for all photographers and their material choices. Therefore, I do not claim absolute validity for these numbers, but I am confident that they apply in most situations where a film has been exposed and developed normally (N), and a diffusion enlarger was used to print onto a bright white photographic paper having a pearl or glossy finish.

The standard densities for negatives and prints change as soon as the film development is altered to control a more or less demanding subject brightness range. When the subject brightness range is larger than normal, a reduced development time is chosen to compensate. The inclusion of additional zones will push all other zones up in density and they will become darker than normal. When the subject brightness range is smaller than normal, an increased development is chosen to compensate. The development time is extended to increase the negative densities of the middle zones, avoiding an otherwise dull negative and print. The exclusion of some zones will pull all other zones down in density and they will become lighter than normal. 'Development and Film Processing' provides more detail on this subject. The next chapter will show how different materials can influence the tonal scale.

## Tone-Reproduction Theory

From the field study conducted by Jones and Condit, we know that the subject brightness range of the average outdoor scene is wider than the density range of photographic paper. We have accepted the zone compression at the highlight and shadow end of the tonal scale to get a full-scale print, but now, we want to know how this compares to an exact reproduction of scene luminance. The theory of tone reproduction is divided into an objective and a subjective, or psychological, method.

The study of subjective tone reproduction compares the visual sensation of the human eye, also called brightness, as a response to the subject luminance of the original scene, to the sensation created when viewing the final photograph and its surrounding areas. We will be discussing some of these effects as they influence our choice of print mounting and illumination in coming chapters, but a more detailed discussion is better left to more specialized scientific literature.

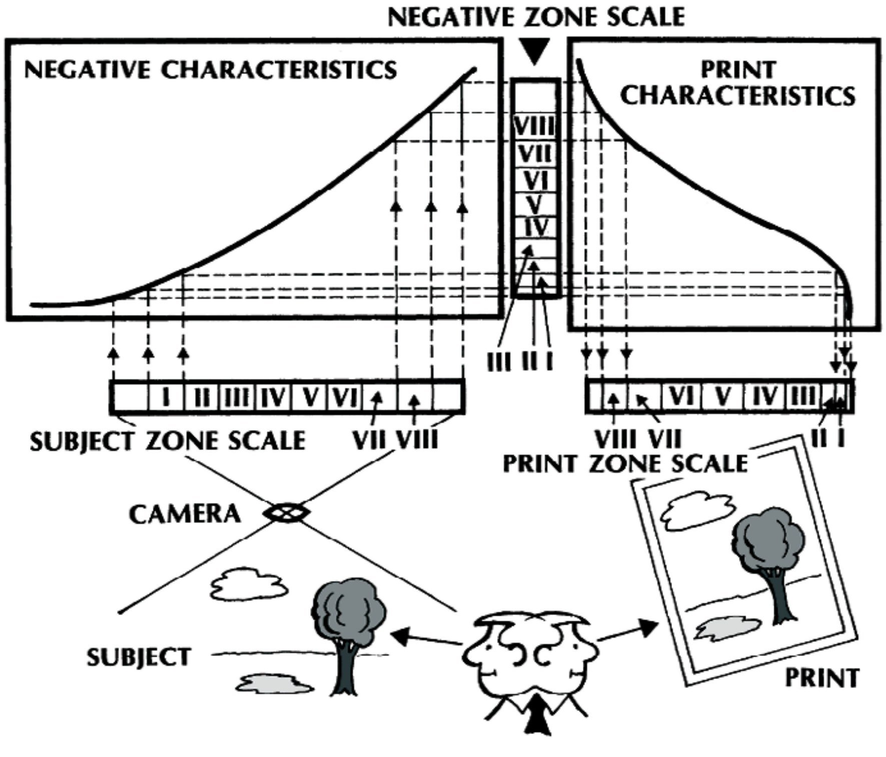


fig.5 This illustration shows how the photographer combines imagination and knowledge to bring the tone-reproduction cycle full circle. Applied with experience, this can be done if the final print is meant to be a close reproduction of the original scene or an artistic expression thereof. (illustration ©1976 by White, Zakia and Lorenz, 'The New Zone System Manual', Morgan & Morgan, Inc. Dobbs Ferry, NY, USA, ISBN 0-87100-100-4)

The study of objective tone reproduction, on the other hand, compares the densities of the photographic print with the log luminance of the original scene. This provides information on how closely the photographic process has come to represent an exact tone reproduction of the subject luminance.

The illustration in fig.5 is a simplified view of how the combination of imagination and skill brings the tone-reproduction cycle full circle. Before the actual picture is taken, the scene is viewed with the final photograph in mind. The photographer takes a look at the scene and forms a mental representation of the intended reproduction. The brightest highlight cannot be brighter than the paper's white, and the darkest shadow cannot be darker than the paper's black. Armed with the necessary experience and knowledge about the equipment and materials used, film and paper are then exposed and developed to create the visualized print. Depending on the photographer's intent, this is done to either obtain a literal recording of the scene or a creative departure from reality.

fig.6 This is an example of a detailed tone-reproduction cycle for normal film development and normal paper contrast. Quadrant 4 shows the resulting objective tone-reproduction curve. In the preferred print, highlight and shadow detail is sacrificed for a higher than objective contrast in the midtones.

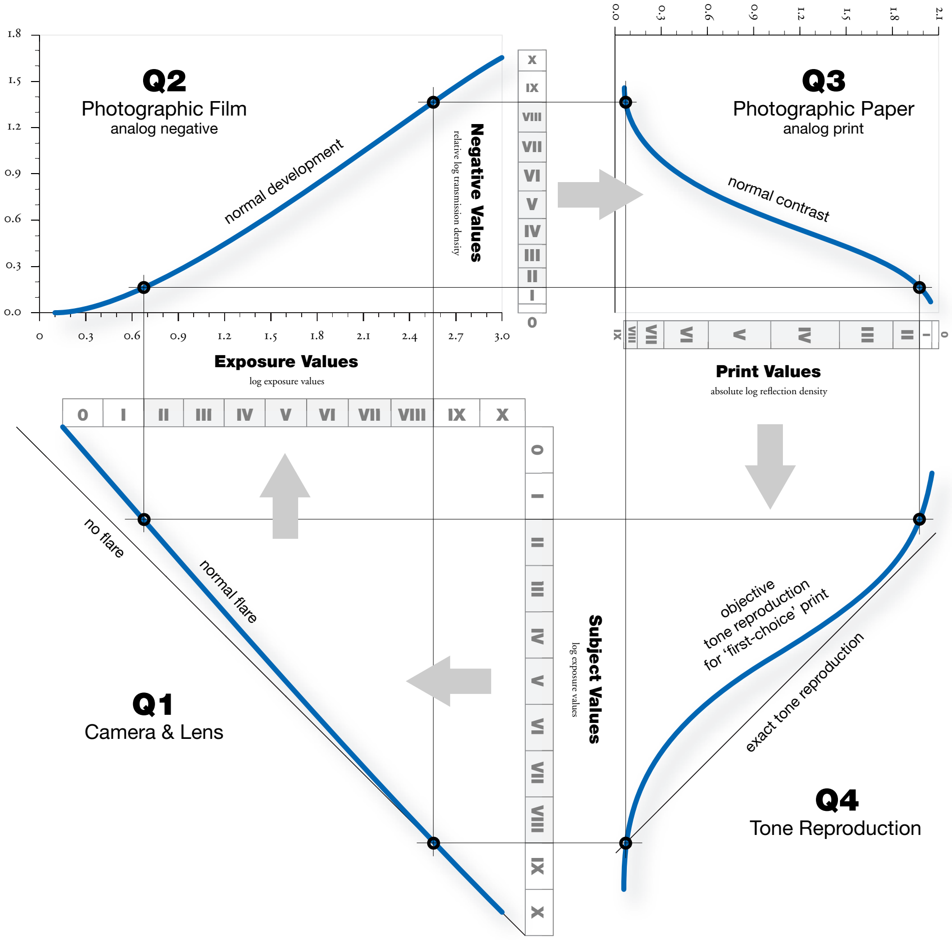

Q2
Photographic Film
analog negative
normal development
Negative Values
relative log transmission density
1.8
1.5
1.2
0.9
0.6
0.3
0.0
0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
2.4
2.7
3.0
Exposure Values
log exposure values
Q3
Photographic Paper
analog print
normal contrast
0.0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
Print Values
absolute log reflection density
0
I
II
III
IV
V
VI
VII
VIII
IX
X
Q1
Camera & Lens
no flare
normal flare
Subject Values
log exposure values
Q4
Tone Reproduction
objective tone reproduction for 'first-choice' print
exact tone reproduction

Fig.6 illustrates a more detailed example of an objective tone-reproduction study for normal film development and normal paper contrast, creating a normal tone-reproduction cycle. Quadrant 1 shows the subject values as they appear in the scene to be photographed, and how they are influenced by camera and lens flare into the film exposure values. These are projected into quadrant 2, and together with their developed negative transmission densities, they build the film characteristic curve. In quadrant 3, the negative values and the equivalent print reflection densities create the paper characteristic curve and the resulting print values. These are projected into quadrant 4, and when combined with the original subject values from quadrant 1, they build the objective tone-reproduction curve. For clarity, only the projection lines for the two endpoints of the pictorial range are shown throughout this tone-reproduction cycle.

If film and paper had straight line characteristic curves, or in other words, if the densities of film and paper were to increase by a consistent amount for every consistent exposure increase, then the tone reproduction would be represented by a straight line in quadrant 4. This exact tone-reproduction line is shown as a reference and can be used to quantify the objective tone reproduction.

As you will see in 'Fine-Tuning Print Exposure & Contrast', material characteristics and practical photographic experience demand optimized lighting conditions for satisfactory print viewing. Print illumination of around 1,000 lux (100 foot-candles) is about ideal. This viewing condition will require an objective tone-reproduction curve similar to the one in fig.6 to meet the standards of subjective excellence. This standard is the result of another study by Loyd A. Jones, C. N. Nelson and H. R. Condit, in which thousands of prints were made from more than a hundred outdoor scenes. They differed in exposure, contrast, density and tone-reproduction curve shape. The reference line was arbitrarily placed so that it intersected with the curve at the highlight point, because it cannot be below the minimum density of the paper. The preferred prints had a curve laying, in average, about 0.3 below the reference line in density (lighter than exact tonal reproduction). The highlight gradients were very low (less contrast), but the midtone gradients were always high, 1.15 and above (more contrast), blending into lower shadow gradients (less contrast again).

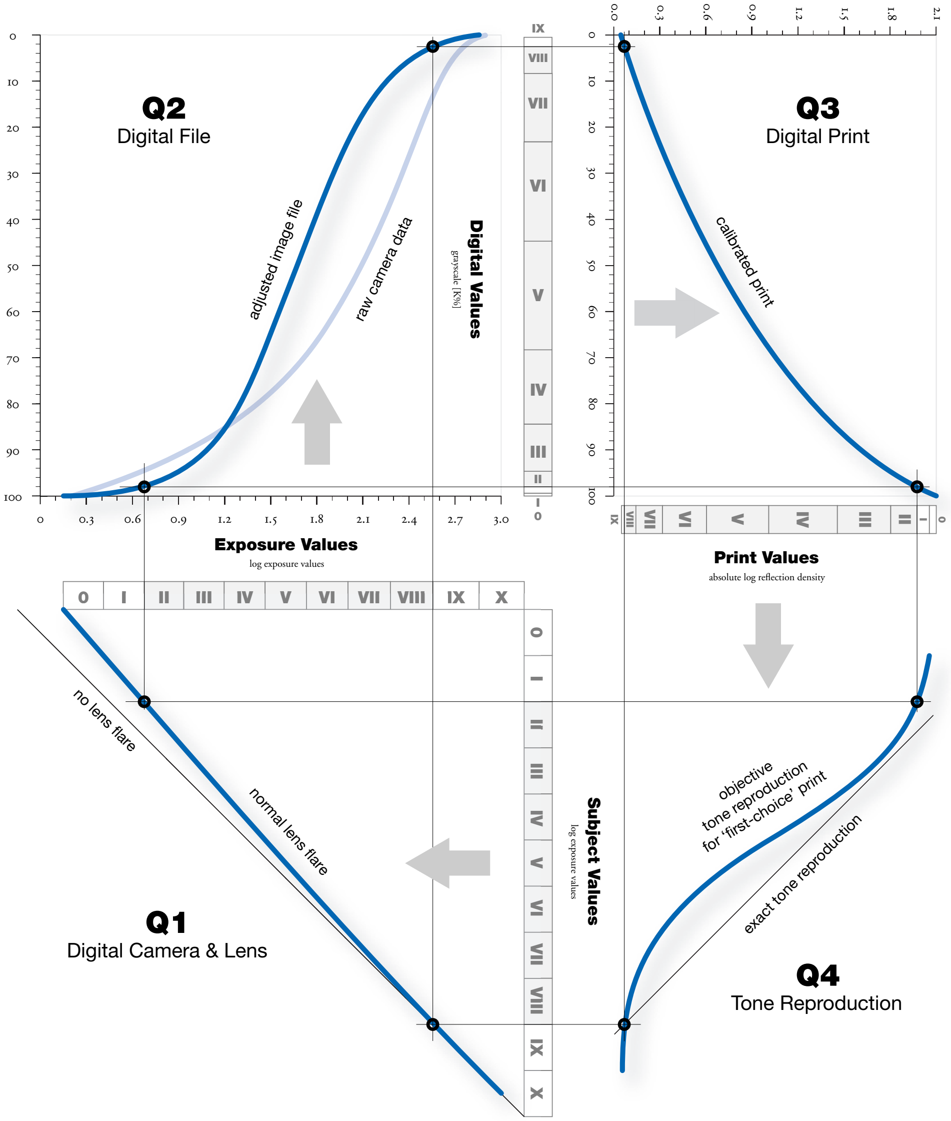
Consequently, a preferred ‘first-choice’ print sacrifices tonal separation in highlights and to some extent in shadows, to magnify separation of the midtones. Whenever the midtone gradient is below 1.10, the print will be judged as being dull or too flat. In addition, the preferred print must be lighter than the exact tone-reproduction curve, since a print with a curve density approaching the reference line was judged as being too dark. This consistent failure of the preferred print to match the exact tone-reproduction curve is thought to be a consequence of normal human eye functionality and its compensation for large luminance ranges in the natural environment. The eye has a definite preference for fine midtone detail and compensates for it with compressed highlights, if a wide scene brightness range should require it. We will use this knowledge to prepare, present and display our photographs accordingly.

## Digital Tone Reproduction

Fig.7 shows an example of a digital tone-reproduction cycle for a digital camera and a calibrated print. Quadrants 1 and 4 are identical to the analog process, since analog and digital camera have similar flare characteristics (Q1), and the preference for a 'first-choice' print does not change with the process of image creation (Q4). However, Quadrants 2 and 3 differ from their analog counterparts, since their vertical scales have been replaced by a digital grayscale ranging from 0-100% (K%). By adjusting the raw camera data, the image file is manipulated until an aesthetically pleasing image is created. This typically happens as a combination of automatic camera adjustment and manual fine-tuning, using image software and a calibrated monitor. The result is stored as a digital file (Q2) and then printed on a calibrated printer to create a digital print (Q3), which satisfies the ‘first-choice’ print requirements. The resulting zone scales are indeed very similar to their analog cousins.

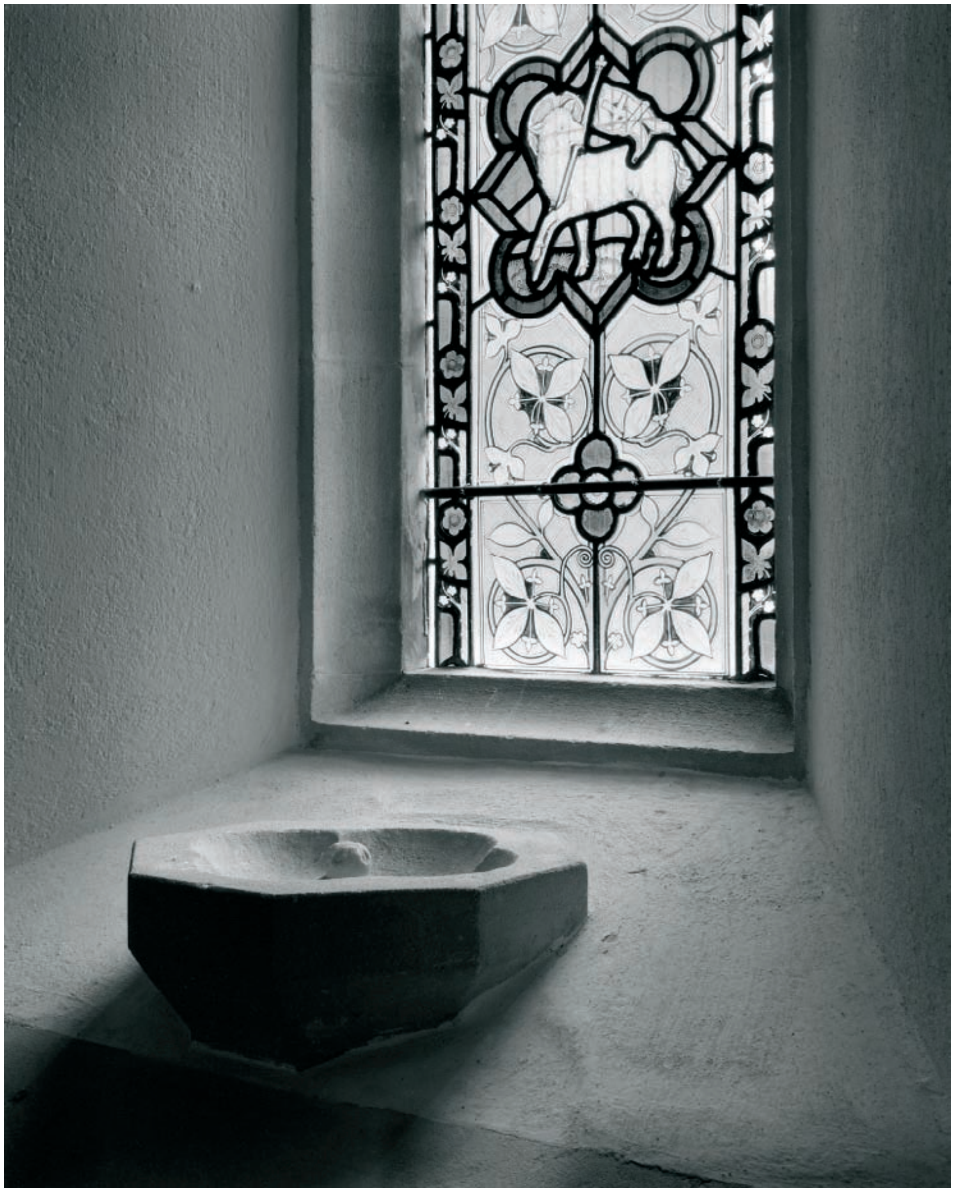
For all practical purposes, negatives and paper, as used in analog photography, are continuous-tone materials. Even the smallest increase in exposure causes a slight density change in the light sensitive emulsions. This results in a print with natural and convincing smooth tones, just as our eyes perceive them. The same is not necessarily the case with digital imaging, since the digital recording of distinct gray levels is limited to a finite amount. This can cause abrupt unsightly tonal changes, also called ‘posterization’ or ‘banding’, whenever low-bit recordings (8 bit) are heavily manipulated. However, this is easily avoided by sensibly manipulating only the high-bit recordings (10, 12 or 16 bit) of raw camera or scanner data files, which is explored a bit further in the next chapter.

fig.7 This is an example of a digital tone-reproduction cycle for a digital camera and a calibrated print. Quadrant 1 and 4 are identical to the analog process, since analog and digital camera have similar flare characteristics (Q1), and the preference for a 'first-choice' print does not change with the process of image creation (Q4).



# Image Gradation

## The influence of material characteristics



In the previous chapter, we clarified how film and paper, through their s-shaped characteristic curves, are responsible for the nonlinear tonal distribution and, consequently, for the image gradation and final tone reproduction of the subject values in the print. Through disciplined exposure and contrast control of film and paper, a photographer can precisely dictate specific shadow and highlight densities (typically the boundaries of the pictorial or textural range), but all other image tones depend exclusively on the individual film and paper selection as well as the interaction of their developed densities. In other words, shadow and highlight extremes can be harnessed through exposure and contrast control, but image gradation and final tone reproduction are material dependent.

So far, we have used idealized curves for film and paper only to keep explanations and graphs representative and independent of material. In this chapter, we will concentrate on the differences of some typical film and paper characteristics to see how they affect image gradation and final tone reproduction.

The possible combinations of available films, papers and developers create an overwhelming quantity of potential characteristic curves (fig.1). Addressing the material uniqueness of individual films and papers would not only be tedious, but it also could never be complete within the context of this book. Nevertheless, there are some common characteristics that significantly influence image gradation and final tone reproduction, and they will be covered here.

### Toe and Shoulder in Films

The toe and shoulder of the film characteristic curve are responsible for print shadows and highlights, respectively. Long toes and shoulders have a low gradient and result in a reduction of local shadow and highlight contrast, compressing the print values more than

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50015-6

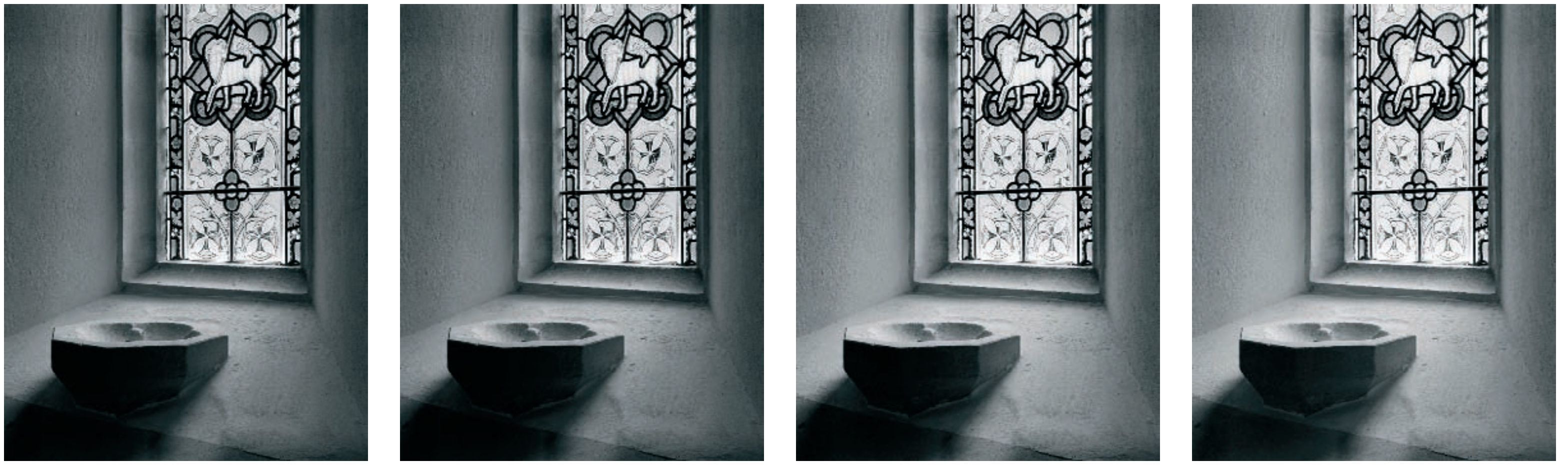


fig.1 All four images have the same shadow and highlight densities and the same overall contrast, but through the use of different films, papers and developers, the images exhibit different shadow, midtone and highlight characteristics. Image gradation changes with material choice.

normal and limiting tonal separation. Short toes and shoulders, on the other hand, have a steep gradient, enhancing tonal separation.

Toe, midtones and shoulder share the representation of the subject brightness range on the film. If one attribute occupies more zones than normal, then the other two have to share the rest. In theory, many combinations are possible, but in practice, it is most likely for a film to have either a pronounced toe or shoulder, not both. A film with a long toe (see fig.2a) leaves less room than normal for midtones and shoulder to build up density. The result is reduced shadow separation with an increasingly steep midtone to highlight gradient and contrast. A film with a short toe and a significant shoulder (see fig.4a) has more shadow separation than normal, but at the cost of reduced highlight separation.

To study the simulated effect of toe and shoulder characteristics, compare fig.2b and fig.4b to each other or to the normal print in fig.3. The highlights in fig.2b are well separated through the absence of a shoulder in the film, but the long toe compresses the shadows and darkenes the midtones. In fig.4b, the film's long shoulder limits highlight separation and lightens midtones, but the short toe increases shadow contrast and separation.

## Toe Shapes in Papers

In the example above, we did not alter the paper in order to study the influence of the film alone. We will now attend to the influence of the paper characteristics, but concentrate our study on the paper toe exclusively, because toe shapes are very different in today's photographic papers, and our limited interest in print densities above 1.89 eliminates most of the shoulder's effect on the final print. Therefore, we can divide today's papers into long- and short-toe papers, as shown in fig.5a and fig.7a, respectively.

As the simulated images in fig.5b and fig.7b show, compared to the normal print in fig.6, the differences are mostly in the highlights where the paper toe is in control. The short-toe characteristic in fig.5b renders good highlight separation with slightly darkened midtones, and the long-toe paper in fig.7b lightened highlights and midtones, but leaves us with a low highlight contrast. There is little difference between the shadows in the three prints.

## Combining Film and Paper

Of course, the final print tones are a result of film and paper choice, and it is, therefore, important to find the right combination. Limited highlight separation, as a result of a pronounced shoulder in the film curve, can be compensated for using a paper with a short toe, or if desired, can be exaggerated with a long-toe paper. Limited shadow separation can be corrected with a short-toe film or a higher paper contrast, but selecting a different brand of paper is unlikely to produce the desired result.

Understanding the variables of image gradation will help you to select the appropriate materials and their combinations. It also will explain why some darkroom enthusiasts swear by one brand of paper, while others claim that it never worked for them. They fig.2a A film having a long-toe and no-shoulder characteristic renders near normal highlight but compressed shadow separation.

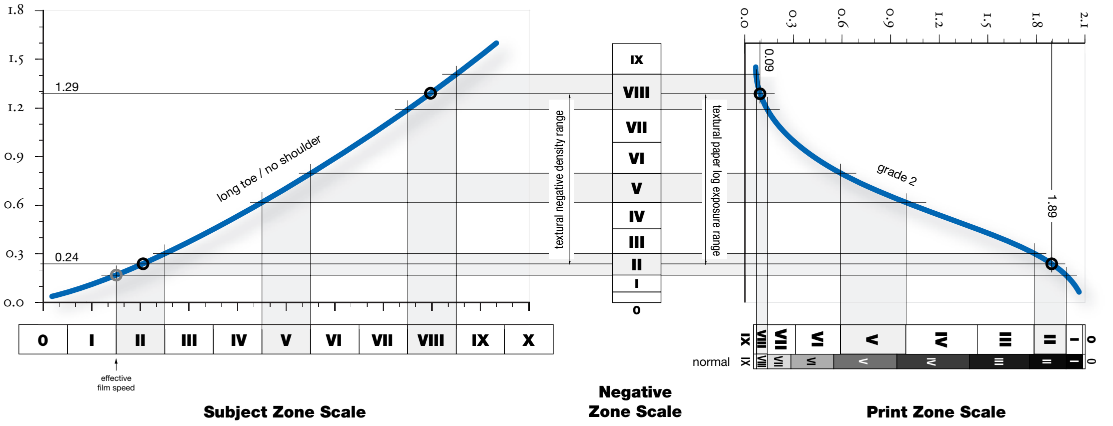
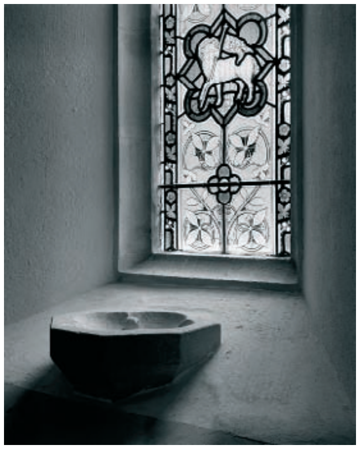
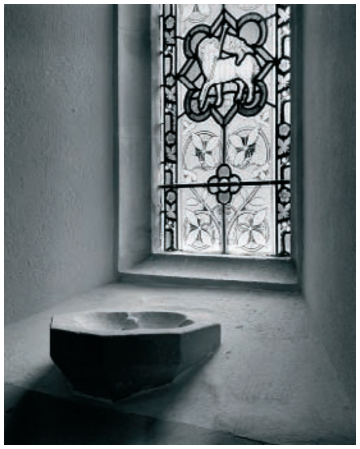


fig.2b (right) The highlights in this print are well separated through the absence of a shoulder in the film, but the long toe has compressed the shadows and darkened the midtones.

fig.3 (middle) This is a comparison print with normal film and paper characteristics. The print has a full tonal scale with normal highlight and shadow detail.

fig.4b (far right) The highlight separation in this print is very limited and midtones are light due to the film's long shoulder, but the short toe increased shadow contrast and separation.


long-toe / no-shoulder film


normal film characteristic

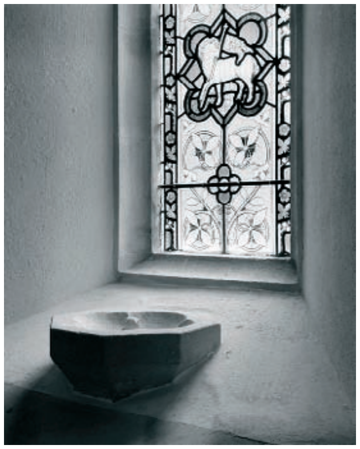
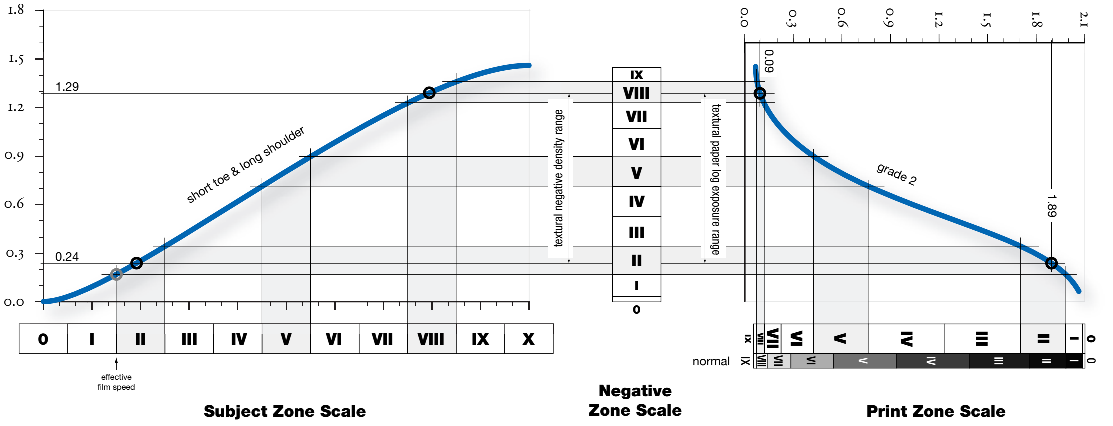

short-toe / long-shoulder film

fig.4a A film having a short-toe and long-shoulder characteristic renders limited highlight separation but delivers increased shadow contrast.



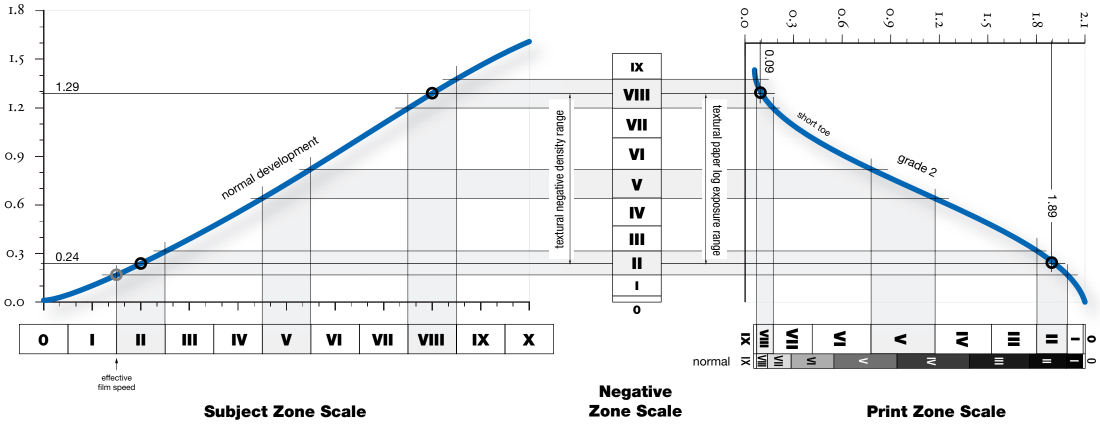
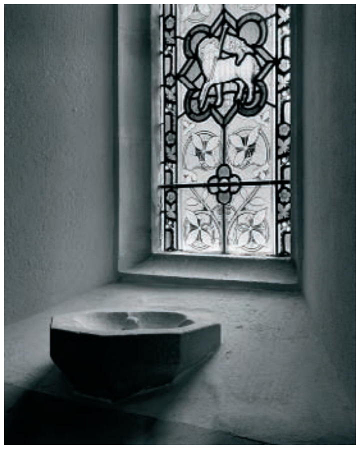
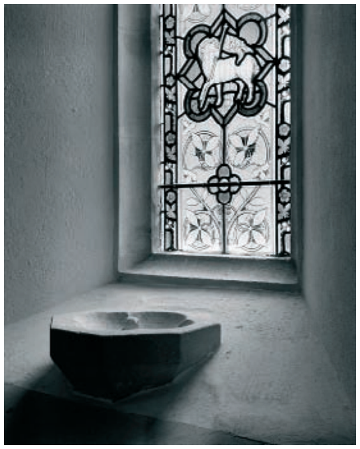


fig.5a A short-toe paper characteristic increases highlight separation and contrast, while darkening midtones.


short-toe paper


normal paper characteristic

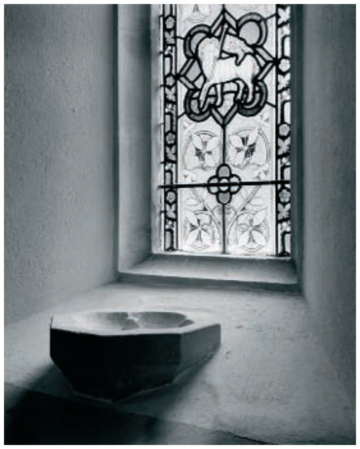

long-toe paper

fig.5b (far left) The short-toe characteristic of this paper results in increased highlight separation with slightly darkened midtones.

fig.6 (middle) This is a comparison print with normal film and paper characteristics. The print has a full tonal scale with normal highlight and shadow detail.

fig.7b (left) The long-toe characteristic of this paper lightened highlights and midtones, but results in reduced highlight separation.

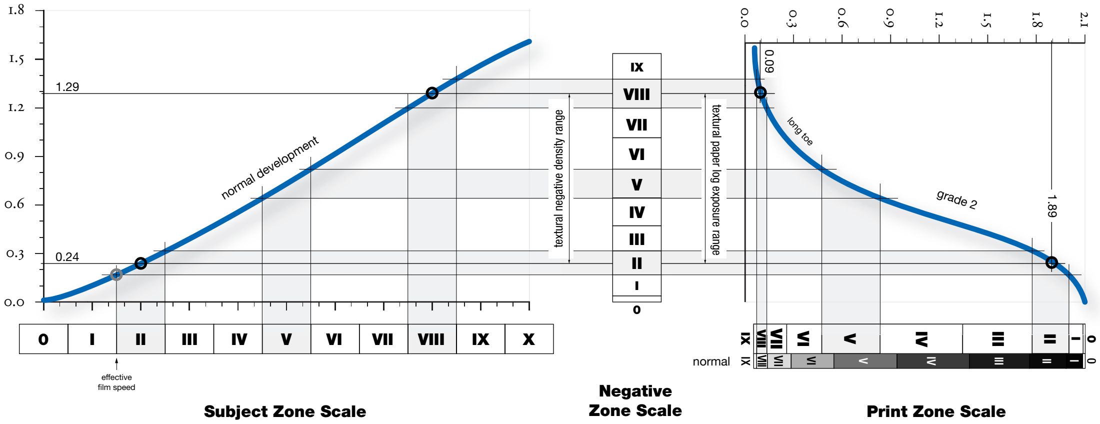


fig.7a A long-toe paper characteristic reduces highlight separation and contrast, while lightening midtones.

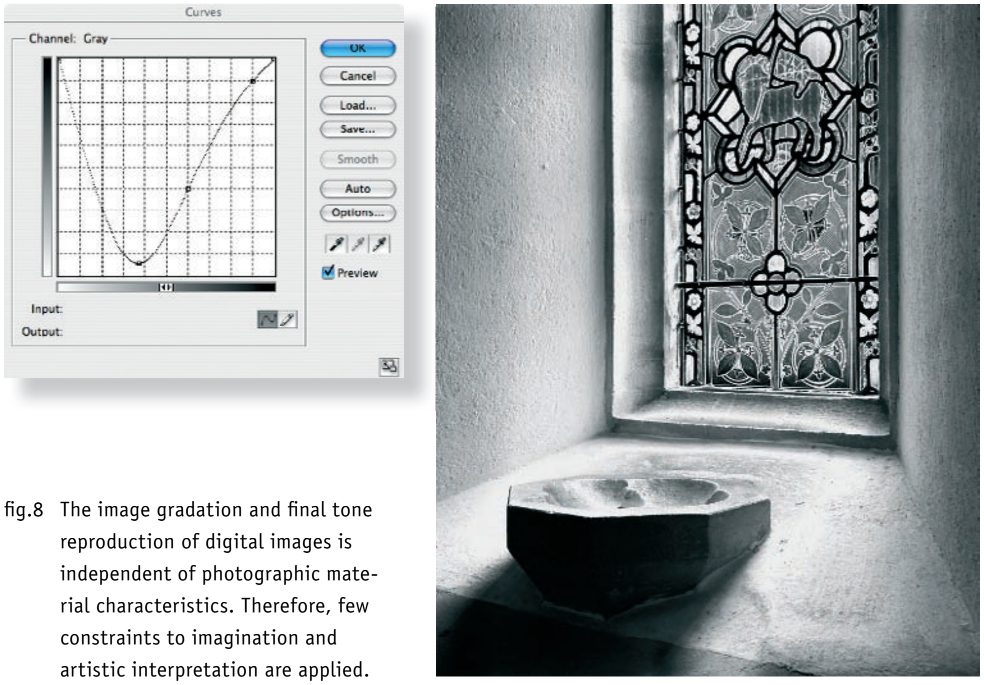
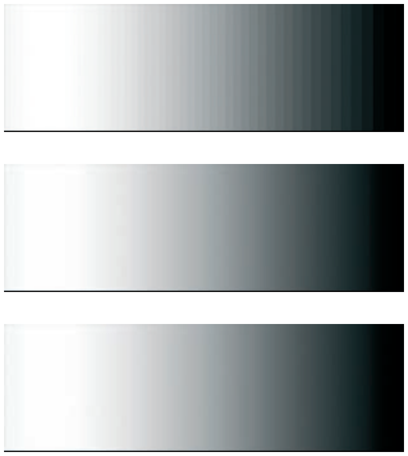


fig.8 The image gradation and final tone reproduction of digital images is independent of photographic material characteristics. Therefore, few constraints to imagination and artistic interpretation are applied.

probably use different films or developers. The final choice depends mostly on the type of photography and personal taste. A sparkling architectural print of a glass building needs more highlight separation than a soft and dreamy glamour portrait. There is no harm in having several different films and papers at hand to be prepared for different subject matter. Just remember, you are more likely to get quality results if you understand your materials thoroughly, rather than having the complexity of your darkroom materials competing with the product offerings of the national photographic wholesaler.



a) severely manipulated 8-bit image

b) severely manipulated 16-bit image

c) 16-bit image (b) converted to 8 bit

fig.9 Severe digital curve manipulation applied to 8-bit images can potentially cause posterization and banding (a). 10, 12 or 16-bit images are required to allow for smooth digital manipulation (b). However, once image manipulation has been concluded, an 8-bit image copy is more than sufficient to support a high-quality print presentation (c).

## Digital Image Gradation

In analog photography, image gradation is controlled by material characteristics as well as the competent selection and combination of these materials. In digital imaging, no such material limits exist, because any realistic or unrealistic tonal distribution can easily be created through skillful curve manipulation alone (fig.8). This leaves the flexibility to either create a faithful representation of the original subject or to support the imagination of the photographer and creatively explore the possibilities of artistic image manipulation, without the material constraints of analog photography. Furthermore, curve manipulation, combined with historical data, can successfully be used to simulate the image characteristics of long-gone film and paper favorites.

What material limits are to analog photography, digital recording limits are to digital imaging. An 8-bit digital capture is more than enough to support a high-quality print presentation, but it cannot be as highly manipulated as a 10, 12 or 16-bit capture, without the danger of posterization or banding (fig.9a-b). Therefore, it is best to capture an image in an as high-bit file format as possible prior to image manipulation. Once image manipulation is concluded, the high-bit image can be converted to 8-bit without hesitation, because its 256 shades of gray make for a smooth representation of all image tones (fig.9c).

## Review Questions

1. What is the main purpose of using the Zone System?
    a. it supports the process of visualization
    b. it makes dodging and burning obsolete
    c. cuts down on waste and eliminates test strips
    d. it always provides a negative which prints on grade-2 paper

2. What is the meaning of Zone V in the Zone System?
    a. the average of the lightest and darkest tone in the scene
    b. a fully textured middle gray with 18% reflectance
    c. the exposure reading of a calibrated lightmeter
    d. 50% gray

3. Does automated metering always suggest the best exposure?
    a. no, because not all scenes are of average reflectance
    b. no, because not all lightmeters are calibrated the same
    c. no, because lightmeters are easily fooled by flare
    d. yes, the average brightness always suggests the best exposure

4. Which is a true statement about the film characteristic curve?
    a. it is not affected by the choice of developer
    b. it can be fully controlled with development techniques
    c. it illustrates the relationship between density and exposure
    d. it has a fixed shape for each film

5. What is the typical subject brightness range of an outdoor scene?
    a. 32:1
    b. 64:1
    c. 160:1
    d. 800:1

6. Which of the following is true about the tone-reproduction cycle?
    a. Zone V never changes
    b. it illustrates the compression of shadows and highlights
    c. it can only be used with film-based systems
    d. it does not account for camera or lens flare

7. What is image gradation?
    a. a measure of print permanence
    b. another word for image contrast
    c. another word for tone-reproduction cycle
    d. the result of film and paper characteristics affecting image tonality

1a, 2b, 3a, 4c, 5c, 6b, 7d

© 1996 by Chris Woodhouse, all rights reserved

# Image Capture

This page intentionally left blank

# Imaging Paths

## Different ways from image capture to final print

There are numerous photographic methods to get from an appealing subject to a fascinating image. To the observer, none of them are of any consequence, because to him or her, the final image is the only reference. If the image is poor to begin with, there is no need to explore it any further. If it is a striking image, however, who cares how it was made? Photographers, on the other hand, do care, because technical expertise and craftsmanship are part of their creative process, and they are always interested in opportunities to explore new techniques and improve their skill.

This edition of the book is exclusively concerned with monochrome imaging. The previous edition was further restricted to dominantly cover analog monochrome photography. This concentrated our efforts on an imaging path involving analog, film-based cameras for image capture, and traditional darkroom work and silver-gelatin prints for image output (fig.1). To us, this is a logical preference, because we trust an analog imaging path to satisfy our high standards of fine-art printing. Even so, there are other methods to create eye-catching images, and this edition of the book gives us the opportunity to explore them in addition to traditional methods.

Fig.1 is not a complete list of all imaging possibilities, but it illustrates that many other alternatives exist. For example, digital cameras and scanners are the direct and indirect gateways to the fascinating world of digital imaging. They either replace the analog film as an image-capturing medium altogether, or they complement the analog input by scanning the film emulsion pixel-by-pixel. After scanning, the analog image information is converted to digital data, which

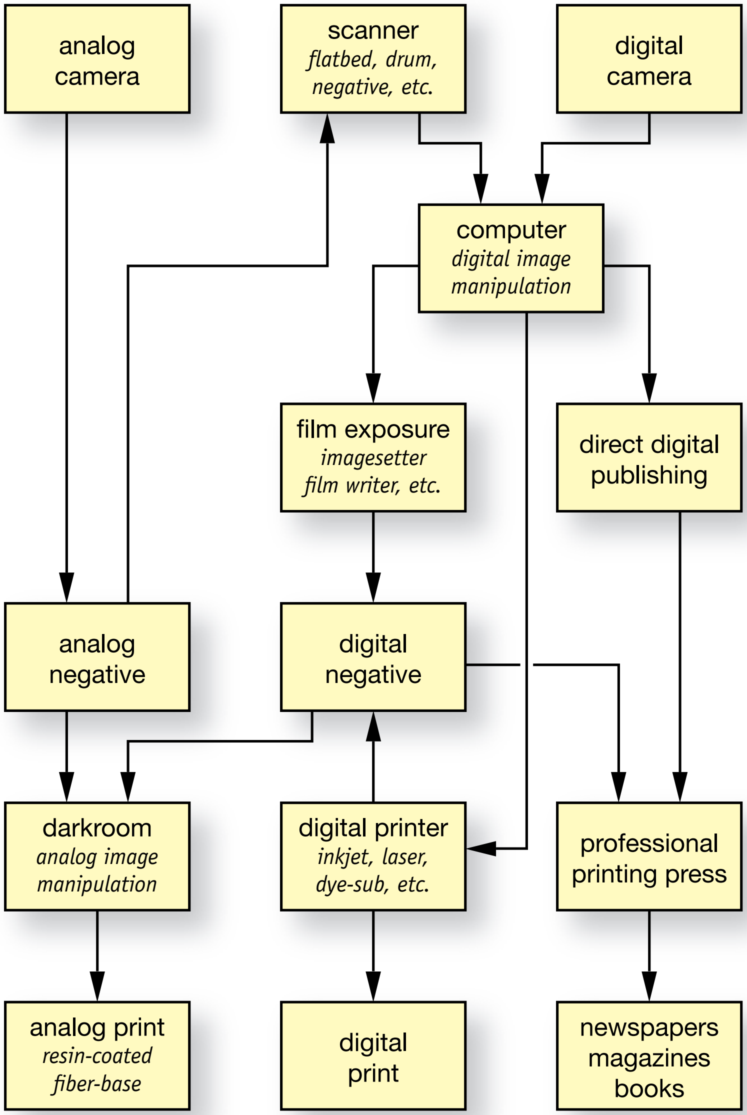

analog camera
scanner
flatbed, drum, negative, etc.
digital camera
computer
digital image manipulation
film exposure
imagesetter film writer, etc.
direct digital publishing
analog negative
digital negative
darkroom
analog image manipulation
digital printer
inkjet, laser, dye-sub, etc.
professional printing press
analog print
resin-coated fiber-base
digital print
newspapers magazines books

fig.1 There are many possible imaging paths to get from the subject to the print, and combining analog and digital elements can help to optimize image quality.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50016-8

is then available for a more flexible computer-based image manipulation. Fundamentally, there is little difference between image manipulation using computer software and tonal corrections in the darkroom. Both are effective tools to optimize the image, highlight what is important and suppress or eliminate what is not. Nevertheless, in some cases, digital image manipulation offers more flexibility and additional opportunities for creative expression. For these cases, it makes sense to temporarily switch from analog to digital in order to gain an additional set of tools for image improvement and optimization.

Unfortunately, many photographers treat this switch like a one-way ticket. Once in the digital domain, they remain there without realizing that an imaging path using analog and digital elements can be more beneficial than a pure analog or digital imaging path alone. They are missing the opportunity to cherry-pick their way along the imaging chain to create the best image possible.

To us, the beauty of a silver-gelatin print is something very special and second to none. Therefore, we continue to concentrate heavily on traditional photographic techniques in order to create an analog print. However, starting with this edition, we use and explain analog and digital capture mechanisms, within their limitations, and integrate darkroom and computer-based manipulations to get the best-looking print possible. In other words, as long as the final output of our creative efforts is a traditional silver-gelatin print, we consider any reasonable deviation from the traditional imaging path an alternative.

For example, modern digital cameras capture just enough image information to satisfy the requirements of standard print observation. However, these images can be manipulated and optimized beyond the possibilities of the standard darkroom, using a computer and imaging software. Afterwards, they can be brought back to the analog domain by creating a digital negative with the help of an imagesetter, film writer or digital printer. Back in the darkroom, the digital negative is contact printed onto traditional photographic paper, and a digital image is successfully converted into a quality silver-gelatin print. To capture even more image data and satisfy the requirements of critical print observation, start with a traditional B&W film or print, scan it at high resolution, manipulate the image data on the computer, and bring it back to the darkroom via a digital negative as explained above. Film remains a viable option until further improvements in digital-camera technology are made. Nevertheless, it will always be an option for people who prefer the security of an additional archive and ever-compatible media.

As you can see, this edition of the book expands the imaging path to include the exciting opportunities and the flexibility of digital input and manipulation, conditional on meeting our quality standards. However, the book also remains dedicated to monochrome B&W photography and still considers silver-gelatin paper to be the best output medium for high-quality prints. Digital negatives open the world of digital imaging to fine-art printers without forcing us into compromised image-output alternatives.

# Sharpness and Depth of Field

## About the limits of human vision and image clarity

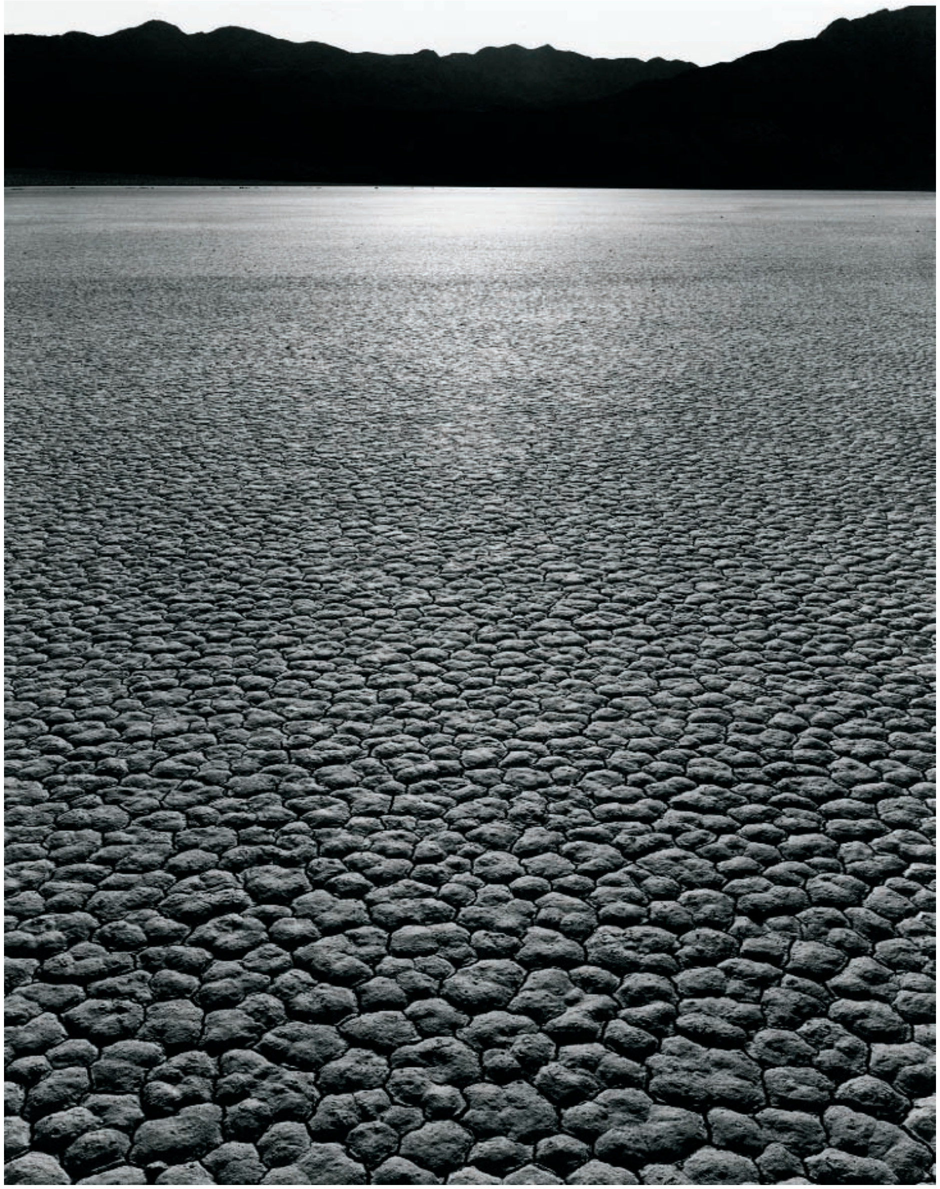
If your camera is precisely aligned and the lens is focused at a specific subject distance, then all objects at precisely this distance are in focus, and strictly speaking, everything else is out of focus. In reality, however, our eyes have a limited optical resolution, and therefore, objects reasonably close to the focus plane also appear perfectly focused in the final print. This creates a zone of still acceptable focus surrounding the focus plane, and objects within this zone are considered to be in focus, while those outside are out of focus. This zone is called the depth of field.

### Limits of Human Vision and Normal Viewing Distance

The limits of human vision differ substantially with the shape and pattern of the object being observed. The eye's capability to recognize a single line is astonishing. A dark human hair is easily distinguished against a well-illuminated white background at a distance of 10 m (30 feet) or more. This calculates to a visual angle of about 1 arc second (0°00'01"). The eye's capability to recognize a single point is less impressive. The size of the smallest object, clearly and consistently visible to most people, calculates to a visual angle of about 1 minute of arc (0°01'00").

Neither of these two tests realistically represents what happens during the observation of a photograph, where visual quality is not challenged by the ability of the eye to detect individual image elements but to resolve fine detail. Several line patterns are used in ergonomic studies to support an objective measure for the resolving power of the human eye. With these patterns, resolving power is measured as the capacity of the eye to discriminate closely spaced lines as separate and distinct line images (see fig.1a).

A commonly agreed result of these studies is that the minimum visual angle at which a line is perceived



© 2001 by Lynn Radeka, all rights reserved

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50017-X

fig.1a-c You can use the USAF/1951 test pattern to check your personal limits of vision. If applicable, conduct the tests using your prescribed corrective glasses.

1.) Place fig.1a in a well-lit area, and evaluate the test pattern from a fixed distance of 1 m (40 inches). Find the group and element where you can still make out a line pattern, and fig.1b will reveal your minimum visual angle in arc minutes.

2.) Place fig.1a in a well-lit area, and evaluate the test pattern from a distance of approximately 250 mm (10 inches). Find the group and element where you can still make out a line pattern, and fig.1c will reveal your near-vision resolving power in line pairs per millimeter (lp/mm).

You can also use the USAF/1951 test pattern to evaluate the performance of your photographic lenses.

3.) Mount camera and lens onto a tripod, and use a fine-grain film to take a photograph of fig.1a from a distance equal to a known multiple of the focal length (25-100x). Consider the use of a cable release and a flash to reduce camera-shake as much as possible. Inspect the negative with a loupe and find the group and element where you can still make out a line pattern. Identify the accompanying resolution of the test pattern in fig.1c, and multiply that value by the focal-length multiplier (above) to find the actual lens resolution in line pairs per millimeter (lp/mm).

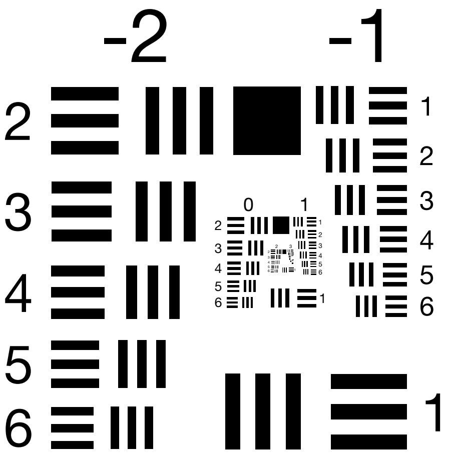


fig.1a The USAF/1951 test pattern is divided into groups with six elements each.

| | groups | | | | | |
|---|---|---|---|---|---|---|
| elements | -2 | -1 | 0 | 1 | 2 | 3 |
| 1 | 6.88 | 3.44 | 1.72 | 0.86 | 0.43 | 0.21 |
| 2 | 6.13 | 3.06 | 1.53 | 0.77 | 0.38 | 0.19 |
| 3 | 5.46 | 2.73 | 1.36 | 0.68 | 0.34 | 0.17 |
| 4 | 4.86 | 2.43 | 1.22 | 0.61 | 0.30 | 0.15 |
| 5 | 4.33 | 2.17 | 1.08 | 0.54 | 0.27 | 0.14 |
| 6 | 3.86 | 1.93 | 0.96 | 0.48 | 0.24 | 0.12 |

fig.1b visual angle in arc minutes (at 1 m distance)

| | groups | | | | | |
|---|---|---|---|---|---|---|
| elements | -2 | -1 | 0 | 1 | 2 | 3 |
| 1 | 0.25 | 0.50 | 1.00 | 2.00 | 4.00 | 8.00 |
| 2 | 0.28 | 0.56 | 1.12 | 2.24 | 4.49 | 8.98 |
| 3 | 0.31 | 0.63 | 1.26 | 2.52 | 5.04 | 10.1 |
| 4 | 0.35 | 0.71 | 1.41 | 2.83 | 5.66 | 11.3 |
| 5 | 0.40 | 0.79 | 1.59 | 3.17 | 6.35 | 12.7 |
| 6 | 0.45 | 0.89 | 1.78 | 3.56 | 7.13 | 14.3 |

fig.1c test pattern resolution in lp/mm

within a pattern of three bars, separated by spaces of equal width, is about 1 minute of arc (0°01'00"). Beyond these studies, empirical tests have shown that common detail and distinct texture are still visible down to about 20 seconds of arc (0°00'20"), a value that must be considered for critical observation. Finally, other factors, such as image contrast and ambient illumination, significantly influence the minimum visual angle. Use fig.1a-c to find your personal limits, but for the rest of this book, the minimum visual angle of the middle-aged human eye is assumed to be between 20 seconds and 1 minute of arc, which is the range from critical to standard observation, respectively.

Of course, the minimum visual angle itself does not tell much about the best optical resolution of photographic detail. We must also be aware of the minimum viewing distance to the photograph. Physiological limitations place comfortable near distance vision at about 250 mm (10 inches), and a most critical viewer may be as close as his or her eyes will focus, investigating all areas of the photograph. Aside from photographic competition judges, this is probably the exception, but at this distance, standard human vision resolves 7 lp/mm (line pairs per millimeter), and critical observation senses detail all the way down to 20 lp/mm, which is still well within the resolution limit of photographic paper (60 lp/mm).

In order to keep depth-of-field scales independent of print size, lens and camera manufacturers make the reasonable assumption that for uncropped prints of 8x10 inches or larger, the normal viewing distance is approximately equal to the print diagonal. For an 8x10-print and the standard minimum visual angle of 1 minute of arc, this calculates to a minimum viewing distance of 325 mm and a resolving power of 10 lines/mm or 5 lp/mm. In other words, at this distance and under normal viewing conditions, the human eye cannot separate print detail smaller than 0.2 mm.

To make an 8x10-inch print from the entire 35mm negative requires about an 8.5-times enlargement. Therefore, negative detail is 8.5 times smaller than its respective print detail, and consequently, the maximum print detail of 0.2 mm has an equivalent maximum negative detail of 0.022 mm (see fig.2). Any 35mm-negative detail smaller than 0.022 mm cannot be resolved during print observation and, consequently, does not have to be in focus on the negative to appear resolved in the print.

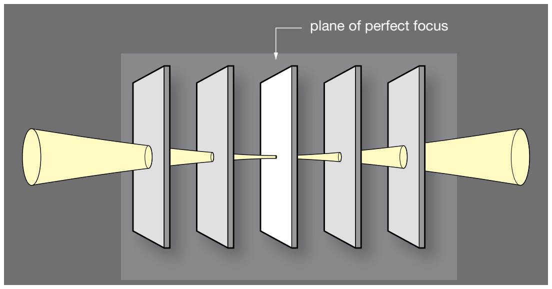


fig.3 A point light source is projected by the lens as a cone of light that converges towards the plane of perfect focus at the film plane, where it forms a tiny point. If focused slightly in front of, or behind, the light, it will change to a small blurry circle. As long as the blurry circle is smaller than the minimum negative detail, it will appear as a point when enlarged for printing. The blurry circle is the 'circle of confusion'. (illustration based on an original by John B. Williams)

| negative format | circle of confusion [mm] | | min negative resolution [lp/mm] | | max infinity-focus tolerance at f/11 [mm] | |
|---|---|---|---|---|---|---|
| | standard 0° 01' 00" | critical 0° 00' 20" | standard 0° 01' 00" | critical 0° 00' 20" | standard 0° 01' 00" | critical 0° 00' 20" |
| 16x24<br>DX format | 0.015 | 0.005 | 67 | 201 | ±0.17 | ±0.06 |
| 24x36<br>FX format | 0.022 | 0.007 | 45 | 134 | ±0.24 | ±0.08 |
| 6x4.5 | 0.039 | 0.013 | 26 | 78 | ±0.43 | ±0.14 |
| 6x6 | 0.042 | 0.014 | 24 | 72 | ±0.46 | ±0.15 |
| 6x7 | 0.048 | 0.016 | 21 | 62 | ±0.53 | ±0.18 |
| 6x9 | 0.052 | 0.017 | 19 | 58 | ±0.57 | ±0.19 |
| 4x5 | 0.089 | 0.030 | 11 | 34 | ±0.98 | ±0.33 |
| 5x7 | 0.112 | 0.037 | 9 | 27 | ±1.23 | ±0.41 |
| 8x10 | 0.179 | 0.060 | 6 | 17 | ±1.97 | ±0.66 |
| 11x14 | 0.252 | 0.084 | 4 | 12 | ±2.77 | ±0.92 |

fig.4 The acceptable circle of confusion for standard and critical viewing conditions depends on the negative format and the optical resolution limits of the eye.

Although we have used the 8x10-print as an example, our assumption of a fixed relationship between viewing distance and print size is appropriate for all print sizes. Any change to the negative magnification is mathematically compensated for by a change in viewing distance. This conveniently keeps the size of the minimum negative detail, for all full-negative enlargements of a given negative format, consistent.

## Circle of Confusion

Imagine the following experiment. In a darkened room, point your camera and normal lens towards the lit bulb of a miniature flashlight placed as far away as possible. The pinpoint light is extremely small and has practically no height or width. If you focus the lens on that light, it forms a tiny point on the view screen. However, if you focus slightly in front of, or behind, the light, it will change to a small blurry circle (fig.3). As long as that blurry circle is smaller than the minimum negative detail, it will look like a point when enlarged for printing. The blurry circle is the 'circle of confusion'.

Except for the purpose of close inspection, we assume that the minimum distance from which a print is viewed is about equal to the print diagonal. This assumption allows us to work with one fixed-size circle of confusion per negative format, because print size and viewing distance grow proportionally. Small negative formats require more negative magnification to produce the same size print than larger formats. Consequently, small negative formats need smaller negative detail and smaller circles of confusion than larger formats. If we assume that the entire negative is printed to produce the print, fig.4 gives standard and critical dimensions for the acceptable circle of confusion, and the minimum negative resolutions required to achieve them, for several negative formats.

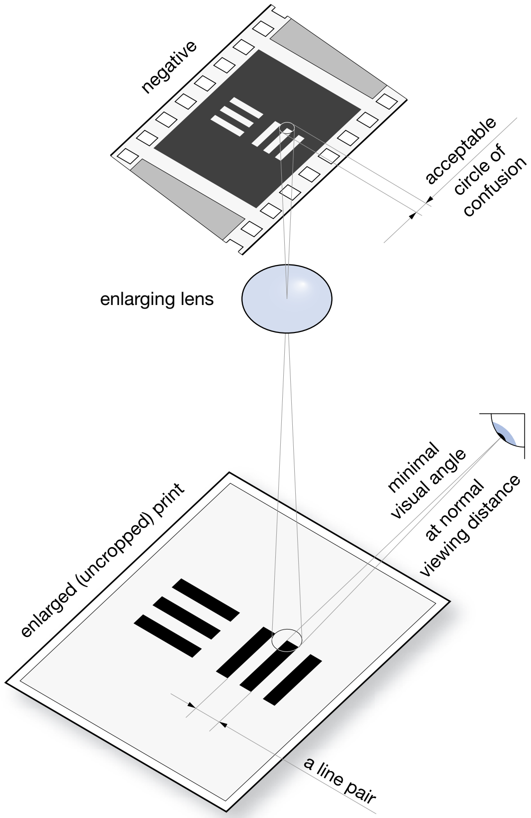

negative
acceptable circle of confusion
enlarging lens
minimal visual angle
at normal viewing distance
enlarged (uncropped) print
a line pair

fig.2 If a print is observed under normal viewing conditions, human vision can detect individual image elements as small as perceived within the minimal visual angle. However, in order to resolve print detail, twice that angle is needed. Making a print from a negative typically requires a certain magnification. The acceptable circle of confusion is smaller than its respective print detail by this factor of magnification. Any negative detail smaller than the acceptable circle of confusion cannot be resolved during the above print observation and, therefore, does not have to be in focus on the negative to appear clear in the print.

## Depth of Field

The flashlight experiment clearly shows that there is a zone of still acceptable focus surrounding the focus plane, and its size depends on several variables in addition to the circle of confusion. The depth of field increases with subject distance and decreases with focal length. As a result, the longer the focal length or the closer the subject, the shallower the depth of field. In macro photography, the depth of field is often reduced to just a few millimeters. Short focal-length lenses provide more depth of field than long focal-length lenses from the same viewpoint, even when the negative is printed with a higher magnification to render the same scale print.

The last significant variable for the depth of field is the lens aperture. Fig.5a-b show how the circle of confusion makes depth of field possible and how the zone increases as the aperture is reduced. In fig.5a, a large aperture limits the depth of field to a relatively small zone. The image circle of a far point is larger than the circle of confusion, and therefore, the point is out of focus. In fig.5b, a smaller lens opening permits only the light that is close to the center of the optical axis to reach the film. As a result, the image is dimmer, but the depth of field is increased.

Closing the aperture by a few stops makes for a significant increase in depth of field. Eventually, the lens aperture is small enough for the depth of field to reach infinity. The tiny aperture of a pinhole camera, often smaller than f/256, produces images approaching infinite depth of field from front to rear.

Quality small- and medium-format lenses have engraved depth-of-field scales as a practical aid for optimal depth-of-field placement or convenient zone focusing. In my experience, many of these scales use a rather optimistic circle of confusion, which makes for an only mediocre depth of field. If you have more stringent requirements, stop the lens one or two stops further down than what the scale suggests, or calculate a personalized depth-of-field table. The equations to calculate the depth of field ($d_F$), and its front (df) and rear (dr) limits, are:

$$d_F = dr - df$$

$$df = \frac{u \cdot f^2}{f^2 + c \cdot N \cdot (u-f)}$$

$$dr = \frac{u \cdot f^2}{f^2 - c \cdot N \cdot (u-f)}$$

$$dr = \infty \qquad \text{for } u \geq \frac{f^2}{c \cdot N}$$

where ‘u’ is the focusing distance, ‘f’ is the focal length, ‘c’ is the circle of confusion, and ‘N’ is the lens aperture in f/stops.

Basic Lens Equations

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

$$u = \frac{v \cdot f}{v - f}$$

$$v = \frac{u \cdot f}{u - f}$$

$$f = \frac{u \cdot v}{u + v}$$

$$m = \frac{v}{u} \quad = \frac{v}{f} - 1 \quad = \frac{f}{u - f}$$

$$N = \frac{f}{d}$$

u = focus distance
v = image distance
f = focal length
m = magnification
N = f/stop
d = aperture

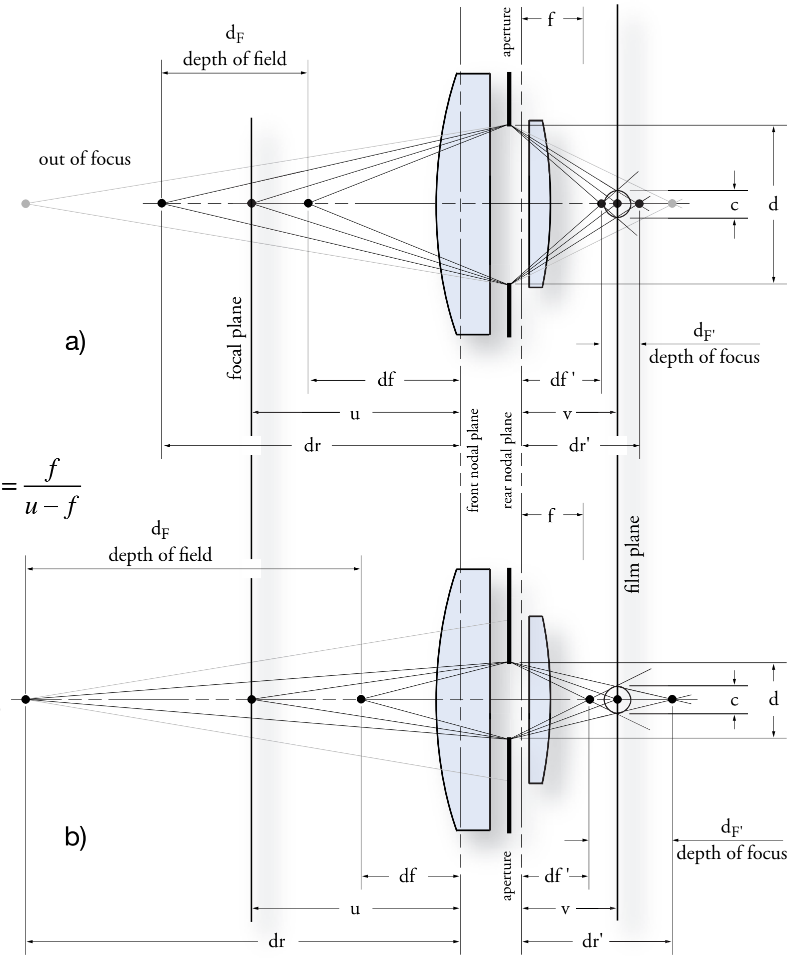


fig.5a-b A smaller lens opening permits only the light that is close to the center of the optical axis to reach the film. As a result, the image is dimmer, but the depth of field is increased.

In case the subject magnification is already known or calculated, the equation to determine the depth of field ($d_F$) simplifies to:

$$d_F \approx 2 \cdot c \cdot N \cdot \left( \frac{m+1}{m^2} \right) \qquad \text{for } m > 0.1$$

where ‘c’ is the circle of confusion, ‘N’ is the lens aperture in f/stops, and ‘m’ is the subject magnification. This equation is adequately accurate for subject magnifications larger than 0.1, which means it can be used for close-up but not landscape photography.

With the help of a spreadsheet and the equations provided here, customized tables for many formats and lenses can be prepared and then kept in the camera bag for future assignments. When performing the computations, be sure to keep units consistent and not to mix imperial and metric units.

### Hyperfocal Distance

Maximum depth of field is obtained in any situation through use of the hyperfocal distance. The hyperfocal distance is defined as the minimum focus distance at which the rear depth-of-field limit is equal to infinity. This has the following consequences: If a lens is focused at the hyperfocal distance, the depth of field starts at half the hyperfocal distance and ends at infinity. But, if the lens is focused at infinity, the depth of field extends only from the hyperfocal distance to infinity (fig.6). The hyperfocal distance ($d_H$) is accurately given by:

$$d_H = \frac{f^2}{c \cdot N} + f$$

or simplified, but adequately accurate given by:

$$d_H \approx \frac{f^2}{c \cdot N}$$

where ‘f’ is the focal length, ‘c’ is the circle of confusion, and ‘N’ is the lens aperture in f/stops.

One noteworthy advantage of using the hyperfocal distance is that, once known, the formulae to calculate the front (df) and rear (dr) depth-of-field limits are much simplified to:

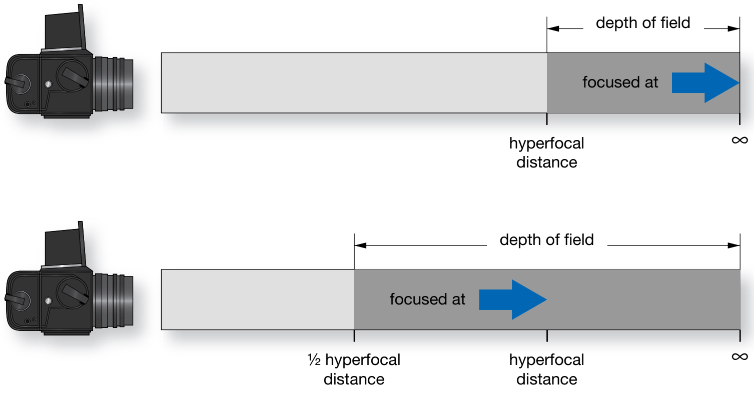


fig.6 If a lens is focused at the hyperfocal distance, the depth of field starts at half the hyperfocal distance and ends at infinity. But, if the lens is focused at infinity, the depth of field extends only from the hyperfocal distance to infinity.

$$df \approx \frac{d_H \cdot u}{d_H + u} \qquad \text{for } m < 0.1$$

$$dr \approx \frac{d_H \cdot u}{d_H - u} \qquad \text{for } u < d_H$$

$$dr = \infty \qquad \text{for } u \geq d_H$$

where ‘$d_H$’ is the hyperfocal distance and ‘u’ is the focusing distance. These simplified formulae lack the accuracy of the equations on the previous page, but they can be used without hesitation for focus distances greater than 10 times the focal length.

## Depth of Focus

As seen in fig.5, similar to the zone of reasonable focus surrounding the focal plane, known as the depth of field, there is an equivalent zone of reasonable focus surrounding the film plane, called the depth of focus ($d_{F'}$).

$$d_{F'} = dr' - df'$$

As the film image is a scaled version of the subject in front of the camera, the depth of focus is a scaled version of the depth of field (fig.7). The front (df') and rear (dr') limits of the depth of focus can be calculated from the front and rear depth-of-field limits by:

$$df' = \frac{f^2}{dr - f} \qquad dr' = \frac{f^2}{df - f}$$

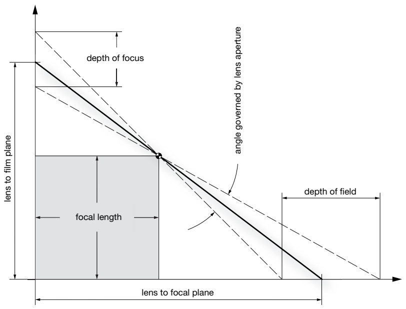


fig.7 This illustration demonstrates the relationship between depth of field and depth of focus. Depth of focus increases with the circle of confusion and magnification. It decreases with increasing lens aperture and is at its minimum when the lens is focused at infinity.

(based on an original by Harold M. Merklinger)

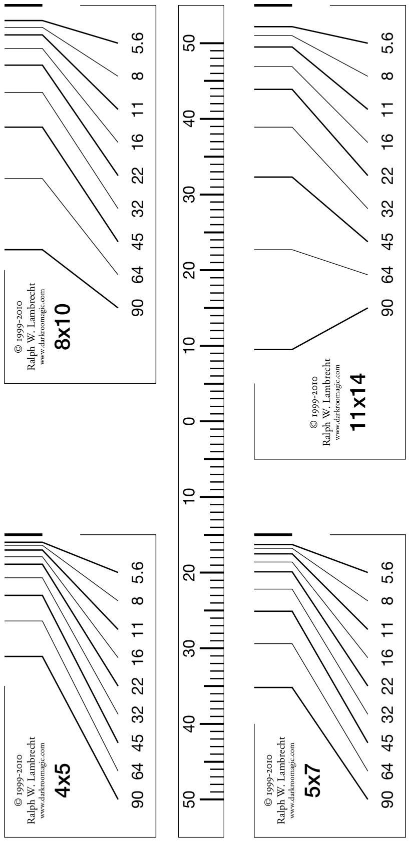


fig.8a (top) The depth-of-focus scale and the gauges shown here are based on the standard circle of confusion for several view-camera formats and can be used with any focal length. Make a copy of each for your personal use.

where ‘f’ is the focal length, and ‘df’ and ‘dr’ are the front and rear depth-of-field limits around the focal plane.

Depth of focus increases with the circle of confusion and subject magnification. It decreases as the lens aperture increases, and it is at its minimum when the lens is focused at infinity. Alternatively, the total depth of focus ($d_{F'}$) is, therefore, also given by:

$$d_{F'} = 2 \cdot c \cdot N \cdot (m+1)$$

where ‘c’ is the circle of confusion, ‘N’ is the lens aperture in f/stops, and ‘m’ is the subject magnification, but the formula simplifies to:

$$d_{F'} = 2 \cdot c \cdot N$$

if the lens is focused at or near infinity, at which point the magnification (m) is insignificantly small and approaching zero.

View camera lenses do not usually feature distance or depth-of-field markings. At first thought, this makes reaching the required depth of field through f/stop estimates impossible, or at least difficult and cumbersome. Nevertheless, since the depth of focus is directly related to the depth of field, this relationship can be used as a reliable alternative when operating a view camera at or near infinity focus.

Fig.8a shows a depth-of-focus scale and gauges for several view-camera formats; fig.8b shows one set in operation. Mount the scale to the monorail or the camera bed of your view camera. Focus the camera on the most distant point for which resolution of detail is required and mark the position of the focusing standard to the scale. Then, focus on the nearest point for which resolution of detail is required, mark its position and measure the distance. Use the appropriate depth-of-focus gauge to translate this distance into the minimum aperture necessary, and slide the focusing standard to the optimum focusing position, located midway between the markings for near and far focus. Each gauge is dedicated to a specific film format but can be used with any focal length, because all gauges are designed for near-infinity focus conditions.

## Diffraction or Limits of Resolution

In practice, lens resolution is limited by two factors, aberrations and diffraction. The resolution limit, due to optical aberrations, depends on lens design and construction, and aberrations are reduced as the lens is stopped down and the aperture gets smaller. Modern lens designs have minimized aberrations, and between f/8 and f/11, lens resolutions of 80-100 lp/mm, or more, are now possible with quality small-format lenses. However, even if all aberrations are completely eliminated, which is impossible, imaging errors due to diffraction will always remain. Diffraction limits the resolution of all lenses, and the best lens, theoretically possible, is a diffraction-limited lens.

Optical diffraction is a phenomenon associated with the bending of light waves when they interact with nearby obstacles in their path. Diffraction causes a beam of light

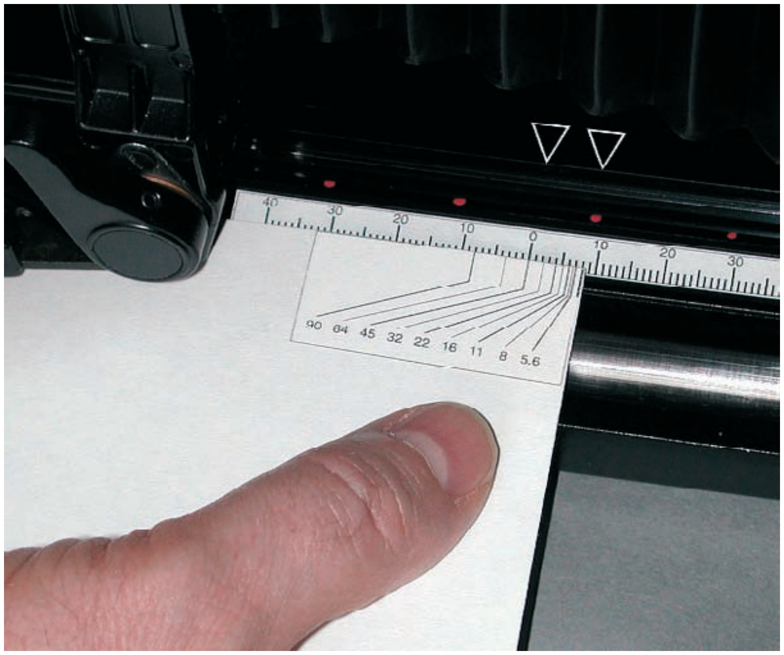


fig.8b (right) Mount the depth-of-focus scale to the camera, mark the near and far focus positions of the focusing standard on the scale, and use the appropriate gauge to translate the distance between them into the required aperture. Then, move the focusing standard to the optimum focusing position, which is midway between the markings for near and far focus. This way, depth of field will be achieved between the near and far focal planes.

to bend slightly, and spread out, as a result of passing through a narrow aperture, and the diffracted light forms a specific pattern. The metal blades of a circular lens aperture, for example, form a circular diffraction pattern, as seen in fig.9.

The English astronomer, Sir George Biddell Airy, first described this pattern in the 1830s, and since then, it is referred to as the Airy diffraction pattern. It presents itself as a bright central disc, the Airy disc, which is surrounded by a set of concentric rings of ever decreasing brightness. The diameter ($d_{airy}$) of the Airy disc is given by:

$$d_{airy} = \frac{2.44 \cdot \lambda \cdot v}{d}$$

where 'λ' is the wavelength of light, 'v' is the distance from lens to image, and 'd' is the diameter of the circular lens aperture (see fig.5). If the lens is focused at infinity, the calculations for the diameter and radius of the Airy disc simplify to:

$$d_{airy} = 2.44 \cdot \lambda \cdot N \qquad r_{airy} = 1.22 \cdot \lambda \cdot N$$

where 'λ' is the wavelength of light, and 'N' is the lens aperture in f/stops. The Airy disc receives approximately 84% of the diffraction pattern's light energy, where the subsequent rings only receive 7, 3, 1.5 and 1%.

Optical diffraction affects the behavior of all light, including the single beam of a point light source. This means that a single image point cannot be smaller than its relevant diffraction pattern. Or, in more practical terms, the smallest possible image point is of the same size as the Airy disc. This fundamentally limits the resolution of any optical system. When observing double stars through a telescope in the 1870s, the English physicist John William Strutt (3rd Baron of Rayleigh) discovered that two stars could just be resolved if their diffraction patterns were at least as far apart as the radius of the Airy disc (fig.10). Since then, this limiting relationship between diffraction and resolution is known as the Rayleigh criterion.

Strictly speaking, a distinction has to be made between point resolution and line resolution, because the human eye responds differently to points and lines. However, the Rayleigh criterion refers only to an approximate relationship between diffraction and resolution, and empirical data shows that it works well for photographic purposes, where minute detail has a variety of shapes.

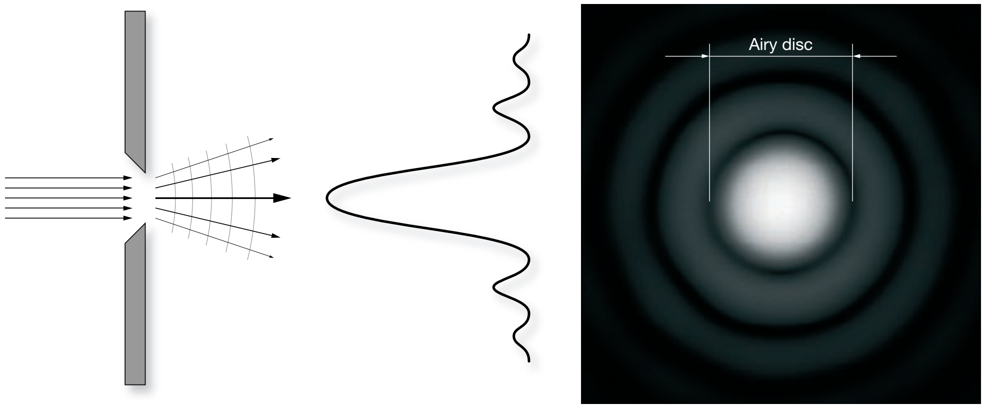
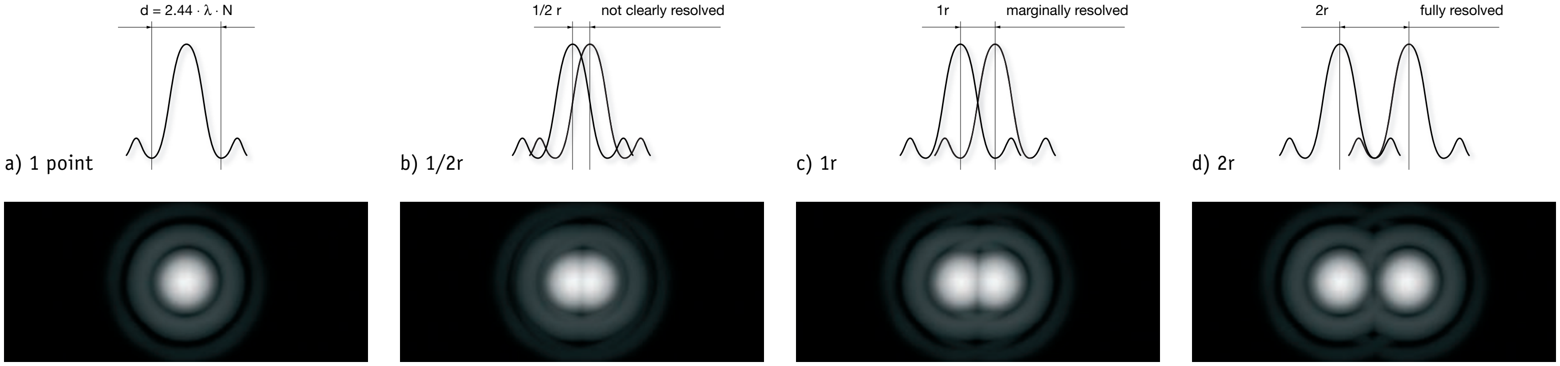


fig.9 Diffraction causes a beam of light to slightly bend and spread out as a result of passing through a narrow aperture, while forming a circular diffraction pattern.



a) 1 point

b) 1/2r

c) 1r

d) 2r

fig.10a-d A single image point cannot be smaller than its relevant diffraction pattern. This fundamentally limits the resolution of any optical system. The Rayleigh criterion states that two image points can only be resolved if their diffraction patterns are at least as far apart as the radius of the Airy disc.

The minimum negative resolution ($R_{min}$), necessary to achieve the required maximum circle of confusion for each negative format (see fig.4), is given by:

$$R_{\min} = \frac{1}{c_{req}}$$

where '$c_{req}$' is the required circle of confusion for either standard or critical observation. Diffraction-limited systems achieve the highest possible lens resolution, because, according to the Rayleigh criterion, they are only limited by the radius of the Airy disc. Maximum lens resolution ($R_{max}$) is given by:

$$R_{\max} = \frac{1}{r_{airy}} = \frac{1}{1.22 \cdot \lambda \cdot N}$$

where '$r_{airy}$' is the radius of the Airy disc, '$\lambda$' is the wavelength of light, and 'N' is the lens aperture in f/stops. Fig.11 shows the diffraction limits for three wavelengths at 650 nm (infrared), 555 nm (the human eye's sensitivity peak) and 400 nm (ultraviolet). Diffraction increases, while aberrations are reduced, as the lens is stopped down. At f/11 or above, lens aberrations are significantly reduced, but diffraction starts to seriously inhibit lens resolution.

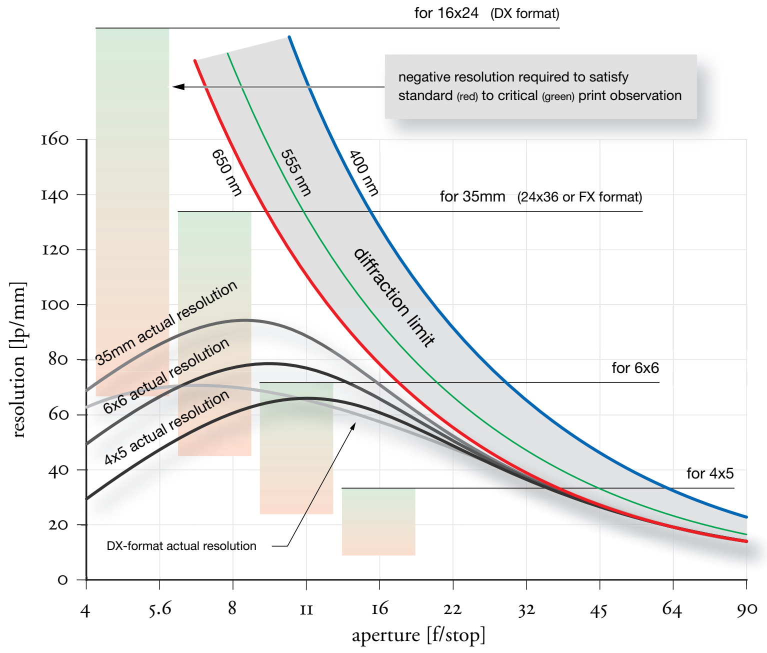


fig.11 The actual negative resolution is limited by lens aberrations and diffraction. When a wide-open lens is stopped down, negative resolution increases at first, because lens aberrations are reduced. Negative resolution then peaks at an 'optimal' aperture for that lens. Stopping the lens down further decreases negative resolution again, due to continuously increasing diffraction. At very small apertures, diffraction is the only limiting factor of negative resolution.

From fig.11, we see that the digital, 16x24mm DX format barely satisfies standard observation requirements, even under the best of circumstances. Critical observation requirements are hopelessly out of reach. The 35mm format fully satisfies standard observation requirements but cannot yield a print 'resolved beyond human detection' either. However, stopping down to about f/8-11 provides maximum lens performance and satisfying prints. A negative made with a high-quality medium-format lens at f/8-11 can be enlarged to a print that stands up to the most critical observation, with little room to spare, but it should not be stopped down beyond f/16 to avoid diffraction. A 4x5 lens performs best at about f/11, but if required, it can be stopped down to f/32 and still achieve the critical resolution necessary for a highly detailed print.

Given a shake-free exposure, many medium- or large-format lens and aperture combinations yield a negative resolution high enough to satisfy even the most critical observer. Nevertheless, take a close look at 'Sharpness in the Darkroom' to make sure you transfer this detail from negative to print. Also, seriously consider the image-quality limits of diffraction when stopping down a lens, because localized softness of secondary image areas is often far less critical than uniform, but mediocre, front-to-back image detail.

The actual lens-resolution values in fig.11 are based on my equipment, materials and procedures. To determine the capabilities of your system, prepare a set of negatives depicting the USAF/1951 test pattern in fig.1a at various lens aperture settings. Subsequently, determine your negative resolutions according to fig.1c, and use fig.4 to compare the results with the negative resolution required to support standard or critical print observation.

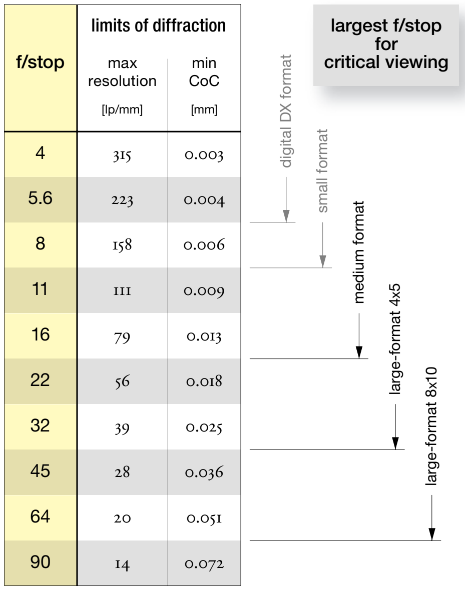
As soon as the radius of the Airy disc is larger then the required circle of confusion, the optical system is limited by diffraction. It is, therefore, futile to compute the depth of field using a circle of confusion smaller than the radius of the Airy disc. As a consequence, the smallest circle of confusion ($c_{min}$) that needs to be taken into account is given by:

$$c_{\min} = r_{airy} = 1.22 \cdot \lambda \cdot N$$

where '$r_{airy}$' is the radius of the Airy disc, '$\lambda$' is the wavelength of light, and 'N' is the lens aperture in f/stops. We cannot improve image quality beyond the quality limits of the entire system. Image quality is ultimately limited by diffraction.

The table in fig.12 lists the diffraction limits in the form of the maximum possible resolutions and the smallest necessary circles of confusion, depending on the lens aperture selected. Like fig.11, the table shows that the potential resolution values for f/4 to f/8 challenge the best of lenses, while even mediocre lenses have no trouble delivering the diffraction-limited resolutions of f/32 to f/90. Fig.12 also indicates diffraction-limited aperture settings for the most popular negative formats. Stopping the lens down further creates a diffraction-limited circle of confusion, which is larger than the one permitted by critical viewing (see fig.4). In other words, stopping the lens down beyond these limits prevents achieving the minimum negative resolutions required for critical viewing. In these cases, either open the aperture, if possible, or do not consider these negatives for critical viewing.

Note that neither the digital DX nor the small 35mm format are suitable for making prints that must conform with the stringent requirements for critical observation. Their lenses, film or camera sensors cannot deliver the minimum resolutions necessary to comply with this high quality standard.



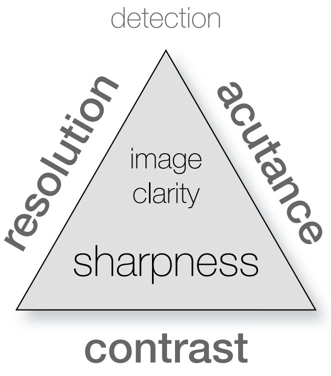
| f/stop | limits of diffraction<br>max resolution [lp/mm] | <br>min CoC [mm] |
|---|---|---|
| 4 | 315 | 0.003 |
| 5.6 | 223 | 0.004 |
| 8 | 158 | 0.006 |
| 11 | 111 | 0.009 |
| 16 | 79 | 0.013 |
| 22 | 56 | 0.018 |
| 32 | 39 | 0.025 |
| 45 | 28 | 0.036 |
| 64 | 20 | 0.051 |
| 90 | 14 | 0.072 |

largest f/stop for critical viewing
digital DX format
small format
medium format
large-format 4x5
large-format 8x10

fig.12 There are diffraction-limited aperture settings for all popular negative formats. Stopping the lens down beyond these limits will prevent achieving the minimum negative resolutions required for critical viewing. Note that neither the digital DX nor the small 35mm format is suitable for critical viewing conditions, because they cannot realistically obtain the minimum resolutions necessary.

## Sharpness and Image Clarity

Creating sharp images is a popular topic of photography, but when photographers start talking about sharpness, they quickly struggle to find precise terminology. This is because they are referring to the visual perception of clear image detail in a photograph, and as with all human impressions, perceptions can be felt but not measured. Detection, resolution, acutance and contrast, however, are aspects of image clarity, and they can be measured. It's similar to 'temperature' and 'heat'. One is a measurable phenomenon; the other vaguely describes our human perception of it. As a consequence, we define sharpness as the visual perception of image clarity, and in general conversation, we can safely assume that 'perceived' sharpness always refers to a mixture of resolution, acutance and contrast.



Resolution, acutance and contrast are inseparably linked to each other, but they are based on different fundamental principles. Resolution is defined as the ability to record distinguishable fine detail. A lens that records more line pairs per millimeter than another offers more resolution. Acutance, on the other hand, is defined as edge contrast, which is the ability to clearly record finite edges between adjacent elements. A black line on a white background is perceived as perfectly sharp if the change from white to black is abrupt (high edge contrast). The smoother the transition from white to black is, the less sharp the line appears. In other words, the higher the edge contrast, the higher the acutance and the sharper the edge. Finally, contrast is a measure of differences in brightness between tones in a photograph. It's the difference between light and shadow, and without

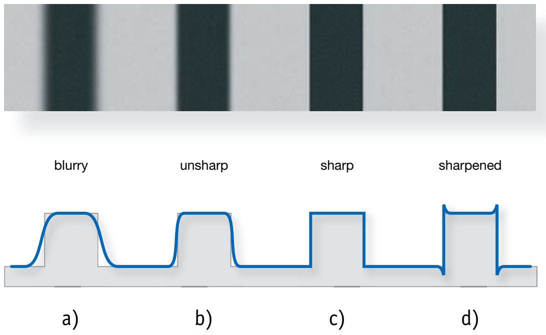


fig.13 Increasingly sharper-appearing lines, with their respective density traces below each, illustrate how perceived sharpness increases with edge contrast.

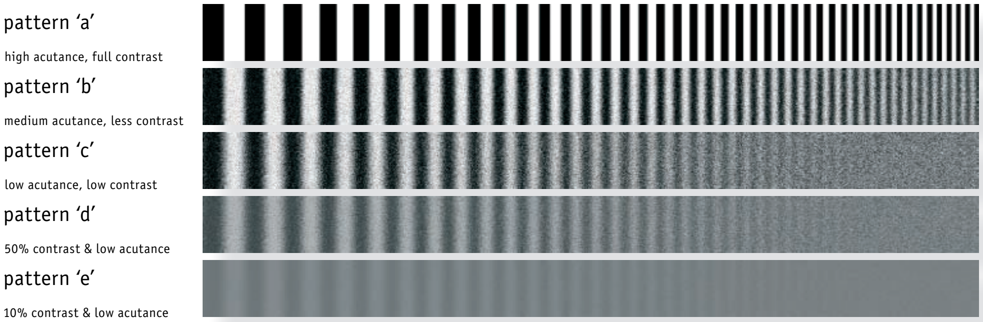
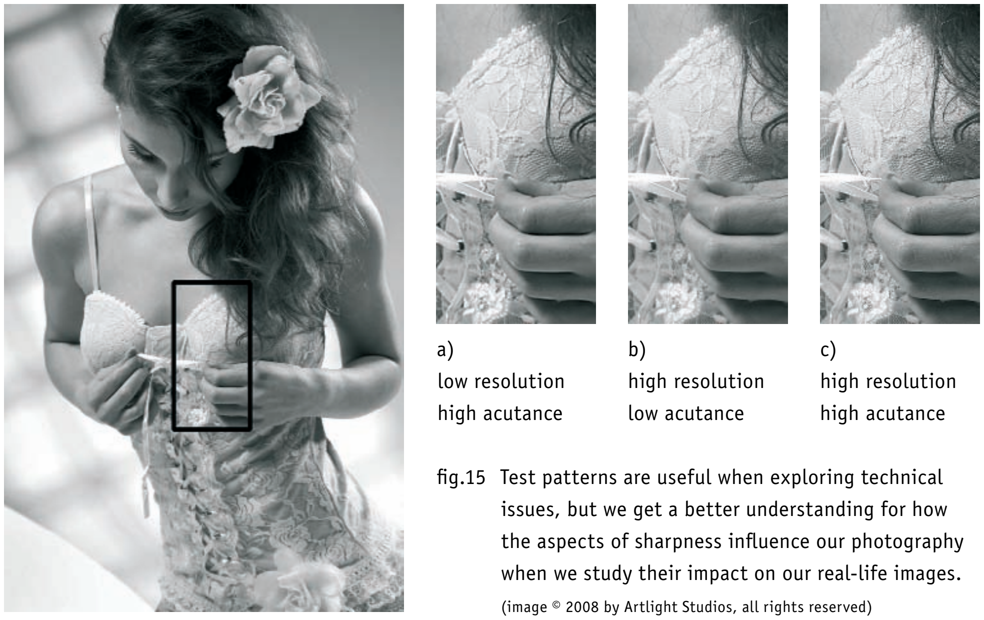

pattern 'a'
high acutance, full contrast
pattern 'b'
medium acutance, less contrast
pattern 'c'
low acutance, low contrast
pattern 'd'
50% contrast & low acutance
pattern 'e'
10% contrast & low acutance

fig.14 Resolution, acutance and contrast are very different measures of image clarity, and sharpness depends on the complex interaction between all three.

that difference, there is nothing to see. There is full contrast between black and white lines, but little or no contrast between gray lines. The more contrast there is between lines, the easier they are to see, and thus, the sharper they appear.

Fig.13 explores different degrees of acutance and illustrates how perceived sharpness increases with edge contrast. Shown are four increasingly sharper-appearing lines, and below each is a density trace across the respective line. The density trace of line (a) has a very smooth density transition from the light-gray background to the dark-gray line. This line does not appear to be sharp at all. Instead, it seems to be totally out of focus and rather blurry. The density trace across the next line (b) shows a more abrupt change in edge density, but the increases and decreases still follow a fairly smooth density transition, which also makes for the appearance of a slightly out-of-focus, unsharp line. The next line (c) is optimally sharp, featuring harsh, clearly defined edges in the density trace. In practice, it is not possible to achieve this high level of acutance with standard pictorial film and full tonal development, but with quality optics, special high-contrast copy films can deliver acutance this high. Nevertheless, it is possible to artificially increase the acutance and get an even sharper line than line 'c', by utilizing the concept of increased edge contrast to its fullest. This can be done in both analog photography and digital imaging. In analog photography, we have a choice between special acutance film developers and unsharp masking, which is discussed in its own chapter. Both methods achieve a line and a density trace similar to the example shown in fig.13d. In digital imaging, almost identical results are obtained, because sharpening algorithms mimic the principle of exaggerated acutance, although with an unfortunate tendency to overdo it.

Fig.14 highlights the complex interaction between resolution, acutance and contrast. It shows the same line pattern with increasing resolution from left to right and decreasing acutance and contrast from top to bottom. Pattern 'a' has optimal sharpness due to the



a)
low resolution
high acutance

b)
high resolution
low acutance

c)
high resolution
high acutance

fig.15 Test patterns are useful when exploring technical issues, but we get a better understanding for how the aspects of sharpness influence our photography when we study their impact on our real-life images.

(image © 2008 by Artlight Studios, all rights reserved)

Sharpness is the visual perception of image clarity. Perceptions can be felt but not measured. Resolution, acutance and contrast are aspects of image clarity, which can be measured. It's similar to 'temperature' and 'heat'. One is a measurable phenomenon; the other vaguely describes our human perception of it. In general conversation, 'perceived' sharpness always refers to a mixture of resolution, acutance and contrast. Despite the fact that using scientific terms loosely may lead to confusion, we also need to recognize that 'sharp' is a commonly understood identifier for image quality. Outside of this chapter, the authors, therefore, take the liberty of using the terms 'sharp' and 'sharpness' to refer to resolution, acutance and/or contrast at the same time, in order to describe a high standard of image quality.

high edge contrast of each line and the full contrast between each line. In pattern 'b', the lines are not as clearly defined, because the edge contrast is reduced (black lines start to 'bleed' into white lines), and consequently, the contrast between lines is slightly reduced. Pattern 'c' seems even less sharp with very smooth line transitions, which result in low contrast between lines. Towards the high-resolution end, the lines actually blend together completely. At some point, no line pattern can be resolved, because there is no contrast left between lines. Patterns 'd' and 'e' are similar to 'c' but the initial, full pattern contrast is reduced to 50% and 10%, respectively, which decreases image clarity even further. As we can see from this example, resolution, acutance and contrast are very different measures of image clarity.

Test patterns are useful when exploring technical issues, but we get a much better understanding for how the aspects of sharpness influence our photography, when we study their impact on our real-life images. Fig.15 shows an example of how resolution, acutance and contrast influence image clarity. In fig.15a, an attempt is made to compensate for low image resolution with increased acutance and contrast. At close inspection (where resolution counts the most), the attempt fails, but at arm's length, the image appears to be sharper than the next. Fig.15b is of high resolution, but a low edge contrast keeps image clarity below expectations. In fig.15c, high resolution is successfully supported by high acutance, and in conjunction, they make for the sharpest image of the three. These examples show that increased acutance and contrast may be able to overcome a limited lack of resolution. But, we can safely conclude that a truly sharp image depends on high resolution, acutance and contrast.

## Modulation Transfer Function (MTF)

Apart from camera sensors or film, lenses are indubitably the most important contributors to image quality. This does not mean that being the proud owner of a good lens is a guarantee for creating good images, but it does provide a solid foundation, and without a sharp lens, it's impossible to get a sharp image. This probably explains why so many photographers feel the need to test their lenses right after the purchase, or why they spend so much time and energy to acquire, and inquisitively study, published lens tests before they invest in a new lens.

A practical and convenient way to measure the optical quality of a lens, without specialized laboratory equipment, is to take a photograph of a resolving power chart such as the USAF/1951 test pattern. As previously explained, resolution measurements alone are not representative of image clarity, but they are a reasonably reliable measure of the fundamental recording characteristics of a lens.

The lens-resolution limit is determined by inspecting the negative with a loupe and finding the smallest, still resolved, line pattern (see fig.1). The benefit of this test method is its simplicity, and if the test is conducted with the photographer's favorite camera, tripod, film, developer and so forth, it's also a reasonable system test. However, because perception and judgment are involved, the test results are highly subjective. The element resolution of the USAF/1951 test pattern increments in 12% steps, and observers rarely agree on the same element representing the highest resolution (fig.16). Also, there is an optimum viewing distance or magnification. If the magnification is too low, the eye cannot separate the smallest, still resolved, line pattern. And, if the magnification is too high, an otherwise resolved line pattern is lost in the noise of micro detail and is not recognized as a coherent pattern, which is why a high-magnification microscope would be of no use. All this makes a 12% variance in test results likely and a 25% variance possible. Nevertheless, a disciplined practitioner, working with reasonable care and consistency, will find this to be a valuable and practical method for comparative testing.

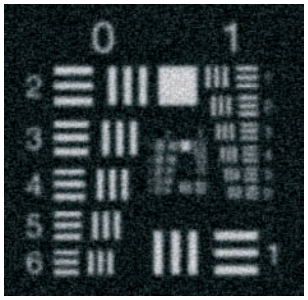
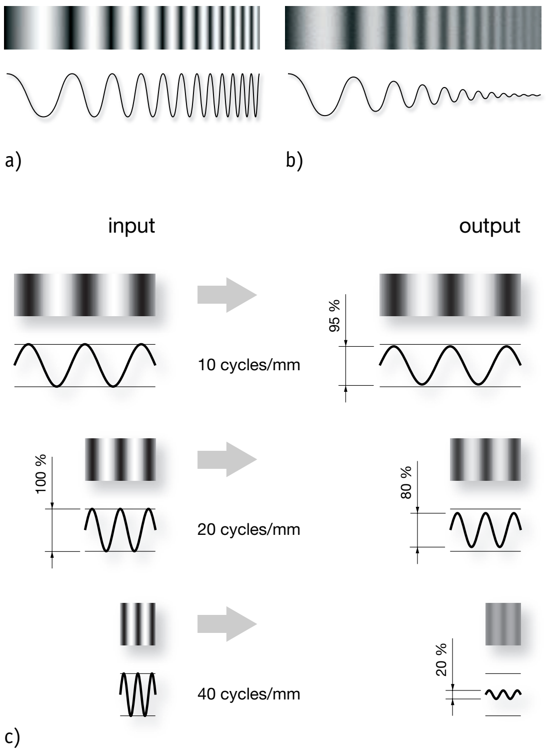


fig.16 A disciplined practitioner, working with reasonable care and consistency, will find photographing test patterns to be a valuable and practical method for comparative testing, but the test results are subjective.

The introduction of the modulation transfer function (MTF) addressed many shortcomings of simply photographing an ordinary line pattern. Today, MTF is the standard scientific test method to evaluate optical lens quality, and simple resolution tests have fallen from favor. Conducting an MTF test is typically beyond the means of an amateur photographer, but it's still worthwhile being able to read and understand MTF charts, because a major benefit of these charts is that they illustrate the complex interaction between resolution, acutance and contrast, which we perceive as sharpness. MTF charts have better correlation to lens quality than resolution measurements alone.

In brief, MTF is the spacial frequency response of an imaging system or component. It is the optical equivalent of acoustic frequency response plots commonly produced for audio systems. The difference is that for audio systems, the frequency is measured in cycles per second (Hz), and for optical systems the frequency is measured in cycles per millimeter (cycles/mm). In both cases, however, the response is measured as a function of the input frequency. This sounds a lot more difficult than it actually is, because the essential principle of the MTF is rather simple (fig.17). Take a well-defined input pattern (a), photograph it (b), and compare the output pattern to the input pattern (c). The ratio of output versus input contrast is called modulation transfer factor, and measured for numerous spacial frequencies (d), results in the MTF.



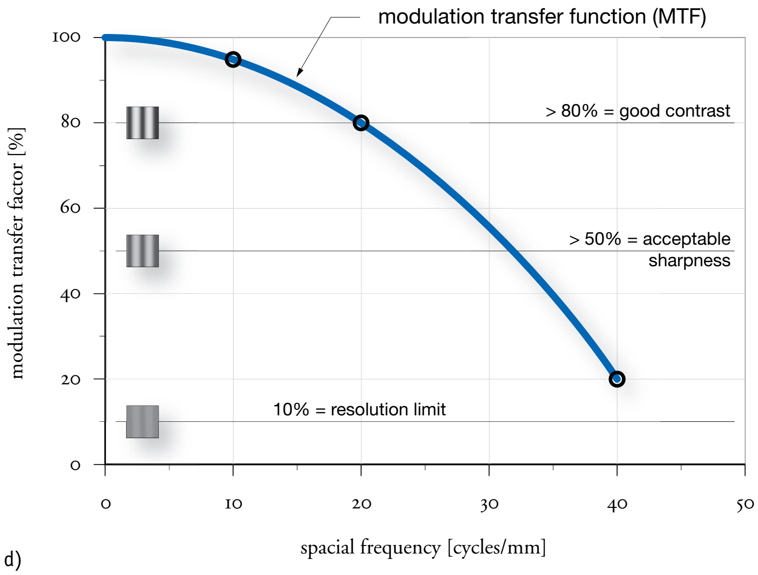


fig.17a-d The essential principle of the modulation transfer function (MTF) is rather simple. Take a well-defined input pattern (a), photograph it (b), and compare the output pattern to the input pattern (c). The ratio of output versus input contrast is called modulation transfer factor, and measured for numerous spacial frequencies (d), results into the MTF, which is a sophisticated and objective optical performance measure of lens quality.

The optimal test target for an MTF evaluation is a sinusoidal pattern, consisting of progressively thinning black and white lines (increasing frequency), whose densities blend smoothly into each other (fig.17a top). A density trace across such a pattern is a sine wave of increasing spacial frequency but consistent amplitude and, consequently, consistent contrast (fig.17a bottom). When such a test pattern is photographed and compared to the original pattern from left to right, low-frequency line patterns on the left are almost identical to the original, but high-frequency patterns on the right are not as clearly recorded (fig.17b top). If the spacial frequency is high enough, the lines eventually merge and blend into a medium gray, leaving no contrast or distinguishable line pattern at all. A density measurement across the pattern from left to right shows that the black line peaks are getting progressively lighter and the white line peaks are getting progressively darker. While the spacial frequency increases, the contrast between black and white lines diminishes, and eventually, there is no contrast left. The pattern disappears into a medium gray. A density trace across the output pattern illustrates this through a continuous loss of amplitude, ultimately leveling out at zero contrast (fig.17b bottom).

The measurement examples in fig.17c show a contrast reduction for spacial frequencies of 10, 20 and 40 cycles/mm, to 95, 80 and 20%, respectively. The ratio of output versus input contrast is called the modulation transfer factor. In practice, the transfer factors of numerous spacial frequencies are calculated, using a multitude of micro-densitometer measurements. After the data is collected, the modulation transfer factors (vertical axis) are plotted against their respective spacial frequencies (horizontal axis), forming the modulation transfer function, as shown in fig.17d.

A contrast response of above 80% is considered to be a good contrast performance, and 50% is still acceptably sharp, but at 10% the image contrast is so severely attenuated that this is considered to be the limit of optical resolution, regardless of the fact that under favorable viewing conditions, contrast responses down to 1% still allow for a line pattern to be perceived. Nevertheless, 10% image contrast roughly corresponds to the Rayleigh criterion, which is generally accepted as the practical resolution limit.

Fig.18 shows a line pattern photographed with three different lenses and compares them with their respective MTFs. Lens ‘a’ represents an unrealistically perfect lens. The recorded image is identical to the test target, and because of this, the MTF is a horizontal line with a 100% modulation transfer factor. This is the ultimate optical performance. Lens ‘b’ is a high-contrast, high-acutance lens of limited resolution, and lens ‘c’ is a low-contrast, low-acutance lens with high resolution. High contrast and acutance do not necessarily mean high resolution. A lens delivering both high contrast and resolution is an optical design challenge. As seen in the patterns of lines ‘b’ and ‘c’, the high-contrast lens ‘b’ appears to be sharper and more brilliant than the high-resolution lens ‘c’. When it comes to perceived sharpness, contrast and acutance are often more important than resolution.

It’s worth noting that MTF tests are often conducted with sinusoidal test targets, as well as line targets. Strictly speaking, spacial frequencies of sinusoidal patterns are measured in cycles/mm, and the resolution of a line pattern is measured in lp/mm. Comparing them directly is not entirely correct, but the test results only show small differences with no practical consequence, and therefore, both units are commonly used interchangeably.

Simple MTFs, such as the ones shown in fig.17-18, are typically prepared for a variety of optical components and systems. You’ll find them for films, paper, scanners, camera sensors and other light-sensitive materials, including the human eye! When it comes to lenses, they don’t tell the whole story, because lenses project the light into an image circle, but the negative format crops this image circle to the familiar square or rectangular shape. Lens quality is best at the image center and gradually worsens towards the edge of the image circle. To more realistically represent lens quality, lens MTFs are limited to a few spacial frequencies, but show the modulation transfer factor across the entire negative format (see fig.20).

Fig.19 shows how lens MTFs are prepared. Small test targets, with fixed spacial frequencies, are placed at a strategic location in the image area. This is done from the center towards the edge of the image circle and up to the corner of the negative format. The test targets include two sets of test patterns, one tangential and one sagittal (radial) to the image circle, because lens performance is not uniform in both directions. Once all test data is compiled, typical lens MTFs can be prepared. Fig.20 shows three medium-format examples, one for a wide-angle, one for a normal and one for a telephoto lens. In typical lens MTFs, the modulation transfer factors (vertical axis) are plotted against the distance from the image center (horizontal axis). Each graph shows the tangential and sagittal lens performance at 10, 20 and 40 lp/mm for one particular focal length and aperture.

A detailed lens evaluation can be conducted from these graphs, if we consider and accept the different spacial frequencies as being representative of different lens performance criteria. The 10-lp/mm line is a good indicator for the contrast behavior of the lens. The 20-lp/mm line represents ‘perceived’ sharpness, and the 40-lp/mm line illustrates the lenses’ resolution limits

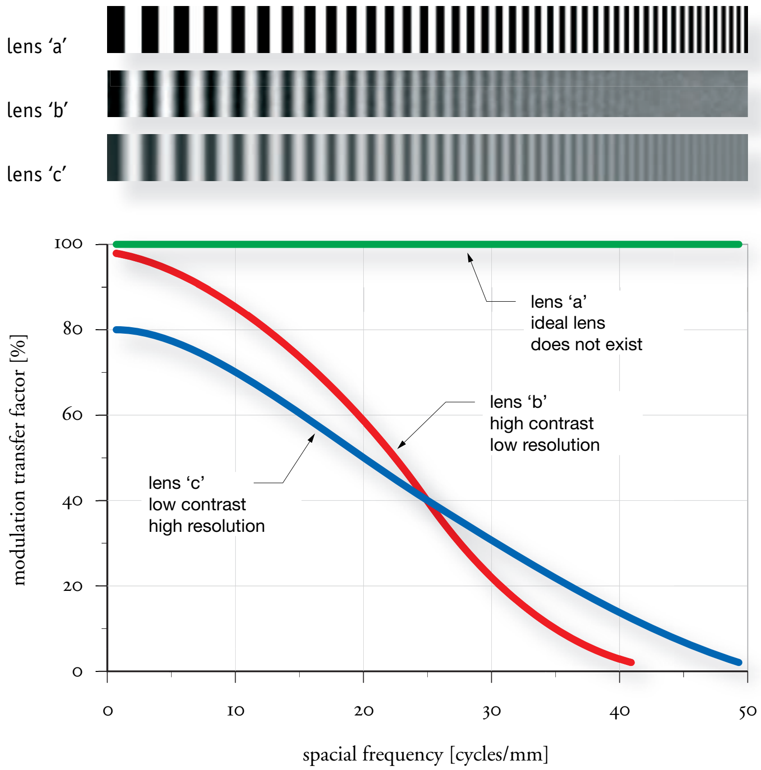


fig.18 The photographs of a line pattern, made with three different lenses, are compared and correlated to their respective MTFs. Lens ‘a’ represents an unrealistically perfect lens. Lens ‘b’ offers more contrast but less resolution than lens ‘c’. High contrast and acutance do not necessarily mean high resolution. The high-contrast lens ‘b’ appears to be sharper and more brilliant than the high-resolution lens ‘c’. When it comes to perceived sharpness, contrast and acutance are often more important than resolution.

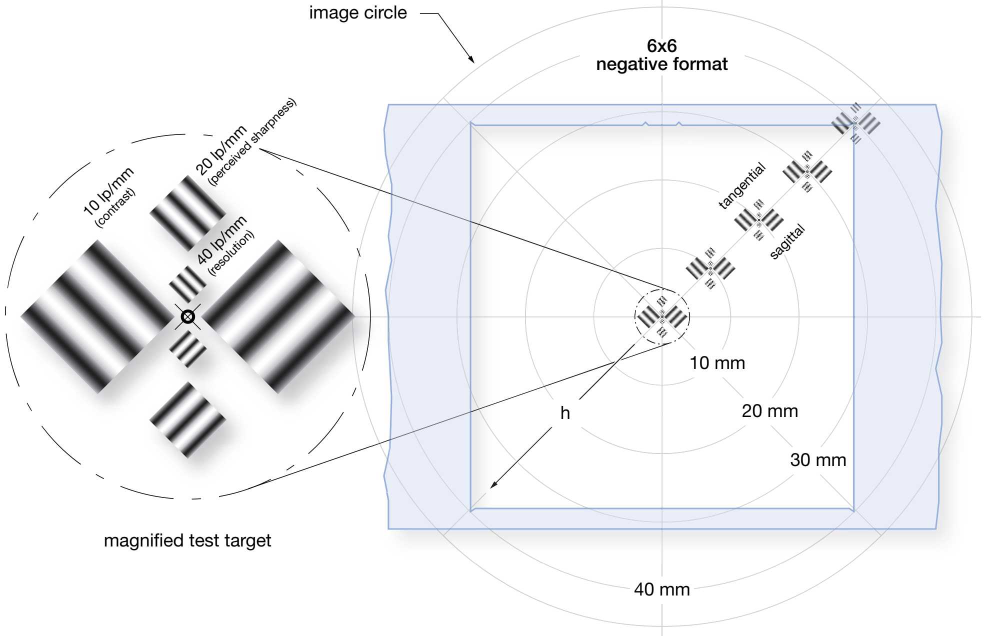


fig.19 A medium-format lens MTF is prepared by placing small test targets, with fixed spacial frequencies, at strategic locations of the image area. This is done from the center towards the edge of the image circle and up to the corner of the negative format.

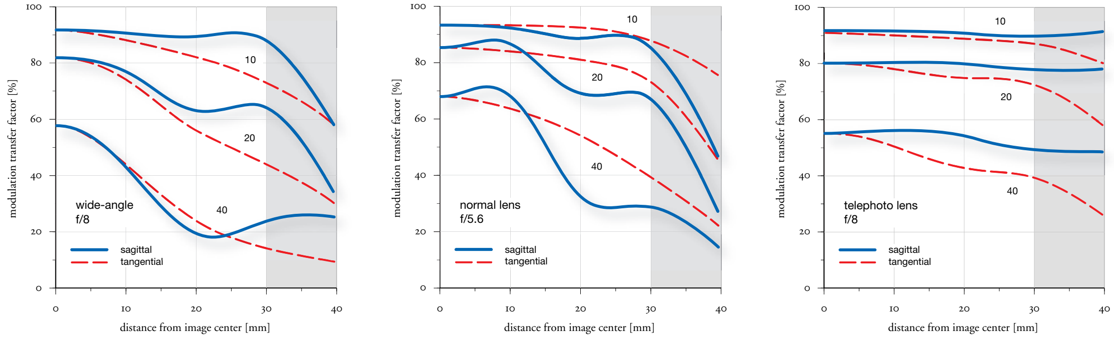
across the negative format. In general, the higher the transfer factors and the straighter the lines are, the better the respective lens performance is. However, what follows are some commonly agreed guidelines, which support a more detailed analysis of lens MTF charts.

Lenses with 10-lp/mm transfer factors (low frequency) of 90% or better have excellent contrast. For a lens to be perceived as truly sharp, 20-lp/mm transfer factors must be around 80% at the image center and not drop below 50% at the borders. A lens is considered to have good resolution if it has 40-lp/mm transfer factors (high frequency) of above 60% at the center and not less than 20% at the image borders.

In general, but not always, longer focal-length lenses are superior to wide-angle lenses, especially at the image corners. When comparing lens performance, only lenses of the same or similar focal length should be judged. The same is true for lens apertures. Wide-open and fully stopped-down lenses don't perform as well as lenses that are stopped down a stop or two to a more realistic 'working' aperture. Never compare a wide-open MTF of one lens to a working-aperture MTF of another. And, don't be overly concerned with the lens performance on the very right-hand side of the MTF chart. Much of it is dedicated to the small corner areas of the negative format. For this reason, these areas are grayed in fig.20a. But, some attention should be given to large performance variances between the tangential and sagittal lines. This indicates the presence of a lens aberration called astigmatism, which, among other things, results in a poor 'bokeh'. Bokeh is a Japanese word, describing the way in which a lens reproduces out-of-focus images.

Despite the complexity of generating them, and the learning curve required to read them, lens MTFs are a valuable method to evaluate absolute lens performance. We need to be aware, however, that some lens manufacturers generate their MTFs from lens-design computer models and not from actual test data. This is better, of course, than having to live with the choice of some lens manufacturers not to generate or publish their MTFs at all. Due to lack of a standard, you may not always find lens MTFs prepared for the same spacial frequencies. Large-format lens MTFs, for example, are often produced for 5, 10 and 20 lp/mm.

MTFs have some inherent limitations. They don't tell us anything about most lens distortions or vignetting, and lens MTFs don't give us a numerical value for the highest resolution obtainable. But, with an MTF at hand, and combined with our own comparative testing, we have all we need to understand the important performance characteristics of our lenses, including sharpness.



a) b) c)

fig.20a-c In these lens MTFs, modulation transfer factors are plotted against the distance from the image center to create the modulation transfer function.

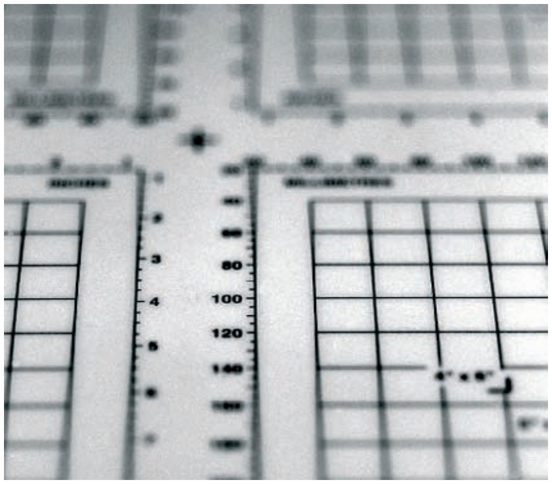
Each graph shows the tangential and sagittal lens performance at 10, 20 and 40 lp/mm for one particular focal length at a typical working aperture.

# Critical Focusing

## What you see is what you get?

Prior to picture taking, we typically focus the image on a view screen, and during the actual exposure, the image is projected onto the film plane. While doing so, we take for granted that view screen and film plane, despite residing at two different locations, have the same distance from the lens.

Camera manufacturing is about balancing process capabilities with customer expectations to achieve a required mechanical accuracy within acceptable tolerances. In addition, all mechanical devices are subject to unavoidable wear and tear, which require periodic adjustment or replacement. To manufacture within tolerance is no guarantee that the product will stay that way forever. Within twelve months, we once had to adjust a professional medium format SLR, two medium-format rangefinders and a well-known make of 35mm rangefinder. One of these cameras was brand-new. After being adjusted, they all focus perfectly, putting the initial camera setup in question, and proving that the following test method is valid.



### What Is Reasonable?

Take, for example, a 90mm, f/2 lens on a 35mm rangefinder. Clearly, the f/2 aperture is not for viewing brightness, but is designed for picture taking. The tolerances of the camera body, lens and photographer add up. The human element in any focus mechanism provides opportunity for error, but it is not an unreasonable assumption that the mechanical focus accuracy should be within the depth of field at the maximum lens aperture. With the 90mm lens at the minimum focus distance, the acceptable depth of field is 10 mm at most. For a portrait, this is the difference between acceptable and unacceptable eye sharpness. The alignment between view screen and film plane must be well within the depth of focus, which in this example, is a tight tolerance of less than ±0.05 mm.

### A Simple Focus Target

For any kind of focus check, we need to be able to set up the camera with perfect repeatability. A good focus target must be easy to focus on and, at the same time, indicate the magnitude of error in focus. This suggests a series of horizontal markings along the optical axis. However, since most split-image and rangefinder screens are better at determining vertical than horizontal lines, adding a series of vertical lines makes good sense. Put these together and you get a grid.

Rather than drawing a unique grid, we can use a piece of graph paper, our cutting-mat scale or the grid on our enlarger easel, all of which make adequate focus targets. For this example (fig.1), we use the grid on an enlarging easel, which is a white piece of plastic with fine, black grid lines in 20mm increments.

The camera is set up on a tripod and carefully focused on the 100mm mark, using the vertical lines for critical adjustment. Additionally, the camera is at an angle of about 30° to the easel plane and close

fig.1 The grid of an enlarging easel or a cutting board makes a perfect focus target for checking critical camera focus.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50018-1

| film type | film thickness |
|---|---|
| roll film | 0.004 - 0.005 |
| sheet film | 0.007 - 0.009 |

| film format | film holder depth | tolerance |
|---|---|---|
| 4x5 | 0.197 | ± 0.007 |
| 5x7 | 0.228 | ± 0.010 |
| 8x10 | 0.260 | ± 0.016 |
| 11x14 | 0.292 | ± 0.022 |

fig.2 Typical film thickness and ANSI film-holder dimensions in inches

to the minimum focus distance. One benefit of focusing rangefinder cameras is immediately apparent when viewing the grid. Since the rangefinder and viewfinder window have a different perspective on the grid, the vertical grid lines have different slants and seem to cross over at the point of focus. Consequently, this enables extremely accurate focus adjustment. With split-image viewfinders, position the split line on the focus point.

As can be seen in fig.1, the gradual blurring of the vertical lines clearly identifies the focus point along the scale, aiding accurate focus measurement. At the same time, it is possible to estimate the range of useful focus at this short range.

We suggest that you repeat the test a few times to ensure your technique. With rangefinder cameras, try arriving at perfect focus from near and far distance settings, to check for any play in the mechanism.

## Improving View Camera Focus

When using a view camera, the image is composed and focused on the ground glass. One surface of the ground glass is textured to provide a means for focusing the image. It is important that this textured surface faces the lens, because it is the image forming side. To take an exposure, the ground glass is replaced by the film holder. At this point, the film must be in the same plane as the ground glass was during focusing, so the negative is perfectly sharp. Camera backs and film holders are machined to tight tolerances to ensure this condition (fig.2).

A well-focused image and full utilization of the intended depth of field are achieved if these tolerances are close to zero. Small deviations can be tolerated, because the depth of focus for view cameras is relatively large (1 mm or 0.040 inch for a 4x5 negative at f/5.6), but even small tolerances will shift the focus and depth of field. It is, therefore, important to keep the ground glass in perfect alignment with the film plane. Fig.2 shows typical film thickness and the ANSI standard dimensions for film holders in inches. However, experience shows that many cameras and film holders deviate enough from these standards to warrant a simple check.

The previously discussed focus target works well for SLRs and rangefinder cameras, but is not ideal for view cameras, the reason being that each test exposure checks only one side of one film holder. It is not uncommon to have a dozen film holders or more, and making dozens of test exposures is time consuming and costly.

## A Simple Check

In his May/June 1999 *Photo Techniques* magazine article, Jack East Jr. proposed a simple but effective alternate method to check whether the ground glass and the film plane are within acceptable tolerance.

Place a piece of film into a holder and insert it into the camera back. Remove the back from the camera, and lay it flat on a table as shown in fig.3. Rest the edge of a rigid ruler across the camera back. Hold a toothpick or cocktail stick vertically against the ruler, lower it until it touches the film and clamp or tape it to the ruler, thereby identifying the film plane location. After doing this with all film holders, leave the toothpick positioned for an average holder.

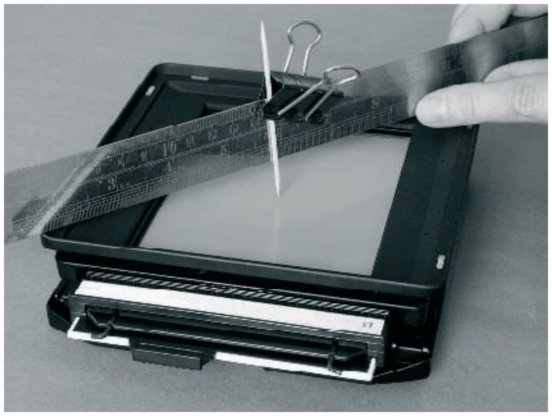


fig.3 (right) A steel ruler, a toothpick and a paper clamp are used to measure the location of the film plane in a 4x5-inch sheet-film holder in relation to the open camera back.

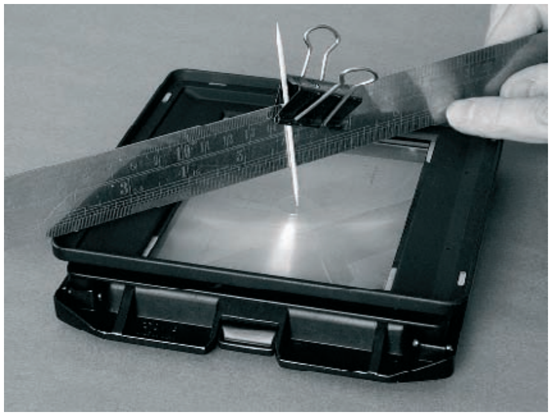


fig.4 (far right) The same setup is used to check for a proper ground-glass location after the film holder is removed, and the toothpick is clamped to an average film-holder depth.

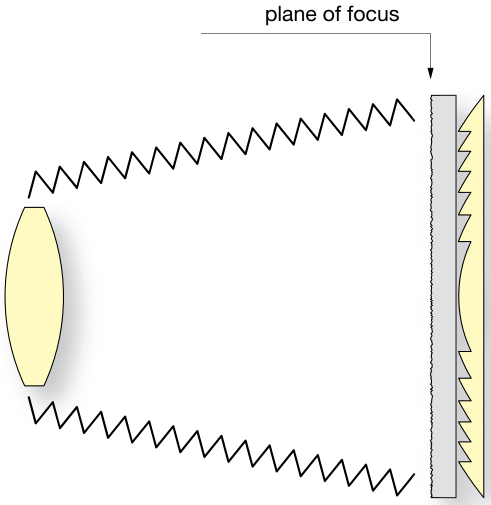


fig.5a (far left) A Fresnel lens can be added to an existing camera back simply by placing it behind the ground glass, in which case, the ground glass maintains its alignment with existing film holders. However, image formation on two separate surfaces can make accurate focusing difficult.

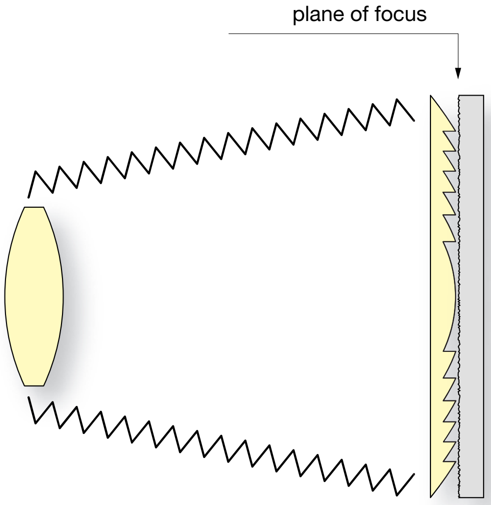


fig.5b (left) The Fresnel lens can be added in front of the ground glass as well, so image formation takes place on only one surface. However, the ground glass is no longer aligned with the film plane, and the camera back must be machined or otherwise adjusted to regain proper focus.

Now, remove any film holder from the camera back, and compare the average film plane with the ground glass location (see fig.4). If the toothpick just touches the ground glass, then no adjustments are required. Knowing that a sheet of regular writing paper is about 0.1 mm (0.004 inch) thick provides a convenient measuring device to quantify any offsets. If the toothpick touches before the ruler, then you can shim the ground glass with paper. If there is an unacceptably large gap between toothpick and ground glass, then professional machining of the camera back is required.

With the toothpick still positioned to identify the average film plane location, measure all film holders for variation. According to the standard in fig.2, a tolerance of ±0.007 inch, or two layers of paper, is acceptable for the 4x5 format. Discard or avoid film holders outside this tolerance.

## Using a Fresnel Lens

One variation in ground glass design is the addition of a Fresnel lens. Its purpose is to provide even illumination over the entire ground glass, making focusing, especially in image corners, significantly easier. A Fresnel lens is typically a flat piece of plastic, with one side built up from a series of thin concentric rings, which function like a lens. The rings are usually barely perceptible to the naked eye, but become obvious when viewed through a focus loupe.

A Fresnel lens equalizes image brightness when placed either in front of or behind the ground glass, and there are some pros and cons with each setup. When a Fresnel lens is added to an existing camera back, it is far simpler to place it behind the ground glass as shown in fig.5a. The ground glass retains its position, and the alignment with existing film holders is maintained. However, in addition to image formation on the textured surface of the ground glass, it is possible to focus an image on the ridges of the concentric rings of the Fresnel lens. The image formation on two separate surfaces can make accurate focusing difficult, but with practice, this is rarely an issue.

Alternatively, the Fresnel lens can be added in front of the ground glass as seen in fig.5b. This has the advantage of image formation only taking place on one surface, since the ridges are in contact with the textured surface of the ground glass. However, if the Fresnel lens is added to an existing camera back, the disadvantage is that the ground glass, and the associated focus plane, is out of its original position. Consequently, the focus plane is no longer aligned with the film plane, and the camera back must be machined or adjusted to allow for the Fresnel lens thickness. In either setup, make sure that the textured surface of the ground glass faces the lens and is aligned with the film plane, and that the ridges of the Fresnel lens are facing the ground glass.

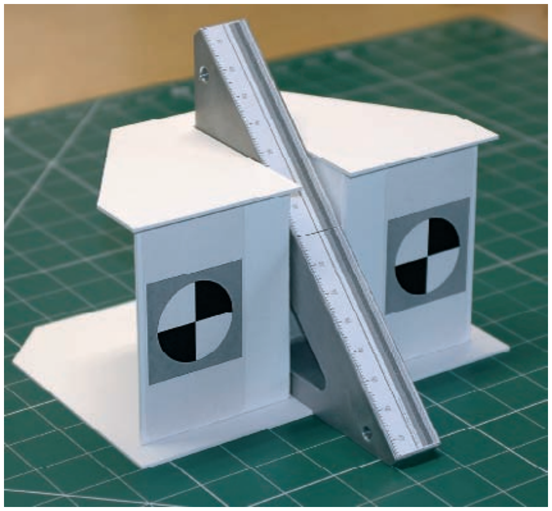


fig.6 An advanced focus target provides quantifiable results.

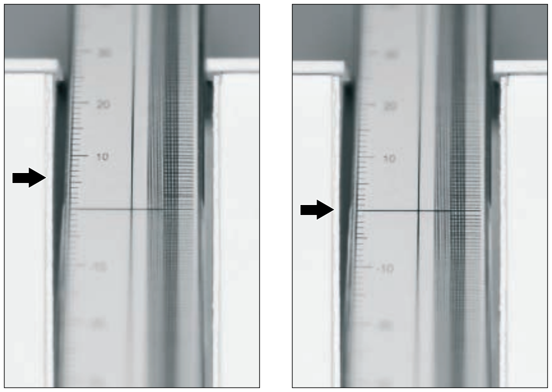


fig.7 These test images were taken from a distance of 935 mm at f/1.8 with an 85mm lens (m=0.1). The image on the left shows a far-sighted focusing error of about 5.5 mm (0.6%), prior to camera adjustment. The image on the right verifies perfect focus after adjustment.

## An Advanced Focus Target

A simple focus target, such as the grid on our enlarger easel in fig.1, is more than adequate to verify camera focus once in a while. But, if you intend to conduct a lot of focus testing, or you need quantifiable results, you might want to invest the time in building a more sophisticated focus target. As an example, our advanced focus target in fig.6 provides repeatable and quantifiable results and is easily made within an hour.

As shown in fig.6, take some mat-board scraps and construct a 45° triangle from it. Make it about 25 mm thick and 150 mm tall. Then, copy the focus scale in fig.8 and glue it to the long side of the triangle. The focus scale is elongated along the vertical axis to be at the correct dimensions if viewed foreshortened under 45°. Building the surrounding support is an option, which makes repeatable focusing a lot easier. When using a support, make sure the focus planes of the support structure line up with the zero marking on the focus scale, before you level the camera and take the picture with a wide-open aperture.

Fig.7 shows two sample test images. The image on the left shows a far-sighted focusing error of about 5.5 mm, prior to the camera adjustment. The image on the right verifies perfect focus after such adjustment.

## A Practical Hint

Focusing a camera in low-light situations is not an easy task. We would like to share a proven technique, which works well even in the darkest church interiors.

Purchase two small flashlights for your camera bag. Mag Instrument is a popular brand, which comes in many sizes. Unscrew the tops, which turns them into miniature torches, and place them upright into the scene at the two extremes of the desired depth of field (fig.9). Focusing on the bright, bare bulbs is simple, no matter how dark the location is.

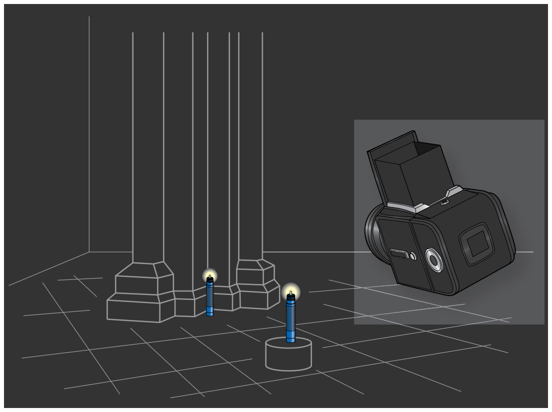


fig.9 Focusing on the bright bulbs of miniature flashlights is simple, no matter how dark the location is.

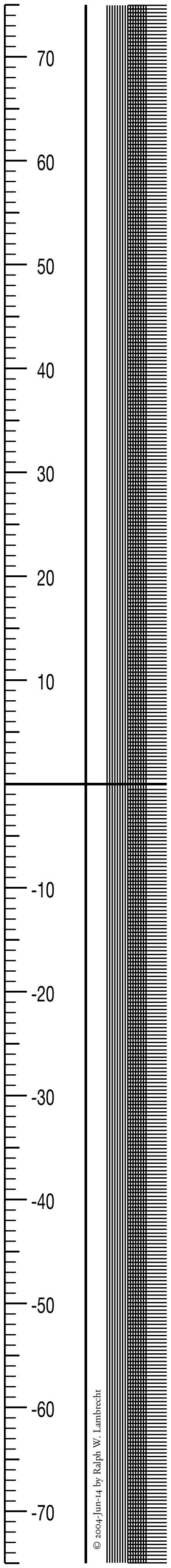


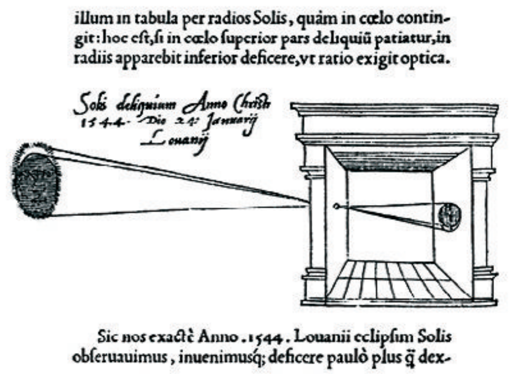
fig.8 This is our advanced focus scale at full size. It is already elongated along the vertical axis to be at the right dimensions if viewed foreshortened under 45°.

# Pinhole Photography

## The fascinating world of lensless imaging

A number of dedicated individuals paved the way for the invention of photography with their accomplishments in several areas of the natural sciences. However, in very basic terms, photography requires only one condition to be satisfied, the successful combination of image formation and image capture.

Image capture has been in the chemical domain for over 150 years, but modern electronics recently added digital image capture as a realistic alternative and provided us with fresh tools for image manipulation. Image formation, on the other hand, was always governed by the laws of optics. It may be of historic interest to note that image formation and capture were practiced independently for some time, before they were successfully combined to make photography



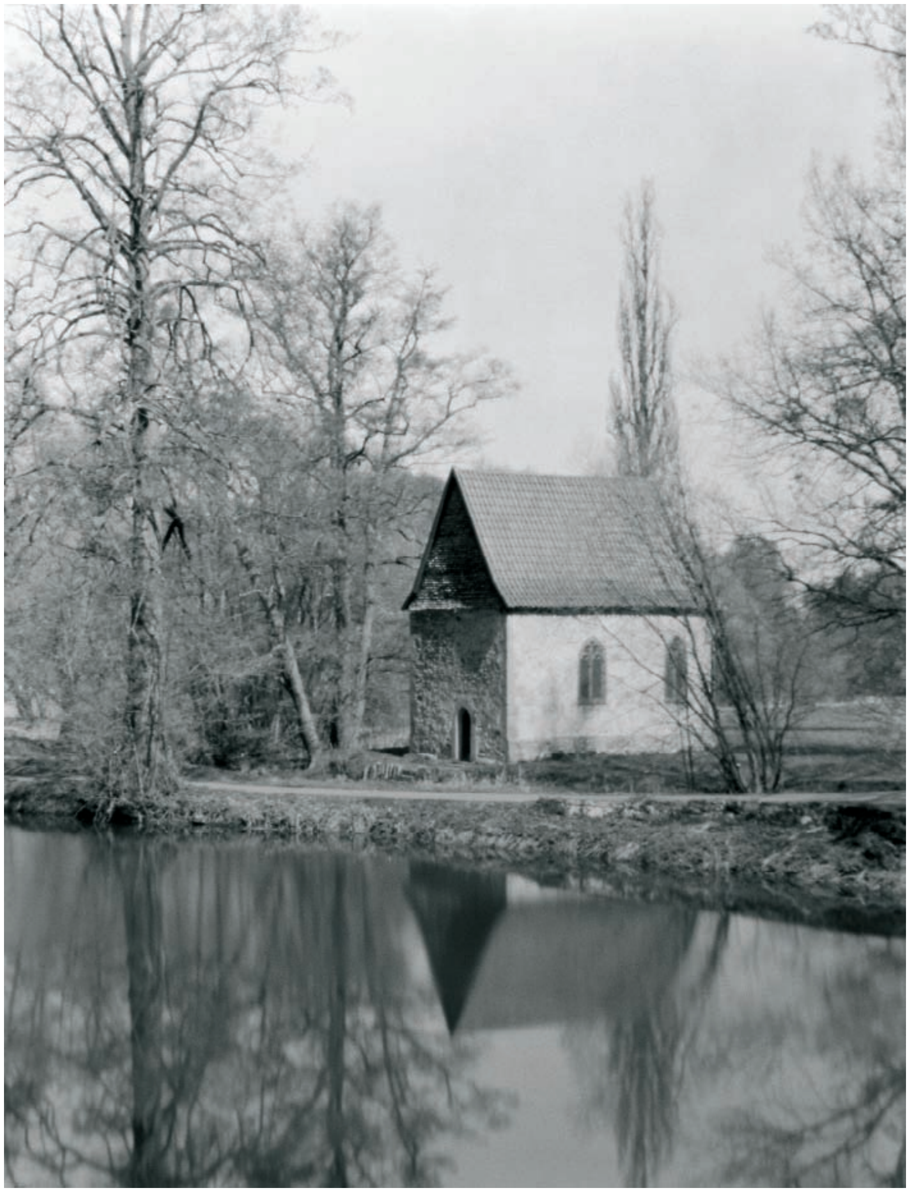
illum in tabula per radios Solis, quàm in cœlo contingit: hoc eſt, ſi in cœlo ſuperior pars deliquiũ patiatur, in radiis apparebit inferior deficere, vt ratio exigit optica.

Solis deliquium Anno Christi
1544. Die 24. Januarij
Louanij

Sic nos exactè Anno .1544. Louanii eclipſim Solis obſeruauimus, inuenimusq; deficere paulò plus q̃ dex-

fig.1 (top) This is thought to be the first published picture of a camera obscura and a pinhole image, observing the solar eclipse of 1544-Jan-24, in the book *De Radio Astronomica et Geometrica* of 1545 by Gemma Frisius.

fig.2 (right) A print made with an 11x14-inch large-format pinhole camera shows surprising detail and clarity.



© 2001 by Andreas Emmel, all rights reserved

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50019-3

possible. Nevertheless, taking a closer look at these building blocks of photography, one quickly finds that image formation is far older than image capture.

Basic image formation is as old as nature itself. The simplest arrangement for basic image formation is by way of a pinhole. The overlapping leaves in trees form numerous pinholes naturally, through which countless sun images are projected onto the ground. It is conceivable that humans were captivated by the crescent pinhole images of an eclipsed sun as early as the dawn of mankind.

The earliest known description of pinhole optics came from Mo Ti in China from around 400 BC, and Aristotle wrote about his observations of the formation of pinhole images in 330 BC. The first known proposals to create a small opening in an otherwise darkened room (camera obscura), in order to intentionally produce pinhole images, came from Alhazen in Egypt around 1020 AD and Roger Bacon (1219-1292) in England. Obsessed with representing realistic perspectives, Renaissance artists, including Leonardo da Vinci (1452-1519), often used a camera obscura to develop the early sketches for their magnificent paintings. In 1584, the second edition of Giovanni Battista Della Porta's book *Magia Naturalis* was published. In this book, he describes the formation of pinhole images and the construction of a pinhole camera in detail. Around that time, Johannes Kepler (1571-1630) coined the phrase camera obscura, which literally means 'dark room'. Soon after, many pinholes were replaced by a simple concave lens, which improved image brightness and quality. Pinhole imaging languished over 200 years, until after the invention of photography, to have its first revival around 1850.

## Image Formation

Image formation starts with light rays, which are either emitted or reflected by the subject. The light falling onto an opaque subject is partially absorbed and partially reflected. Theoretically, reflection is either directional (specular) or multidirectional (diffuse). In reality, the actual reflection depends on the surface characteristics of the subject and is always a mixture of specular and diffuse reflections. Smooth surfaces, such as glass, mirrors, polished metal or the calm surface of a lake, create predominantly specular reflections. Rough surfaces, such as leaves, stone, cloth or dry skin, create primarily diffuse reflections.

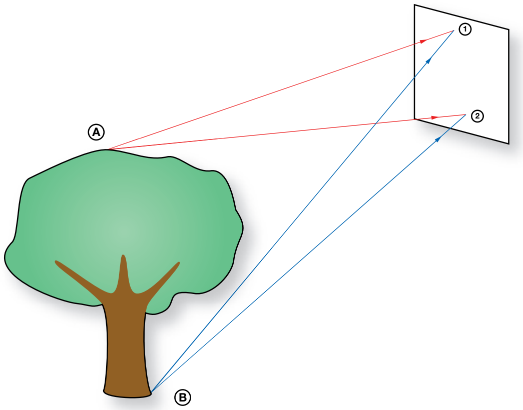


fig.3a Simply holding up a card in front of a subject is not sufficient to create an image, because every point on the card receives light rays from numerous points on the subject.

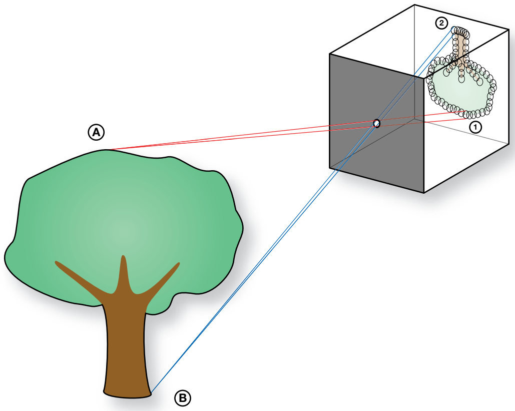


fig.3b But if an opaque panel, containing a tiny pin-sized hole, is placed between the subject and the card, the panel blocks all light rays coming from the subject with the exception of a limited number entering through the pinhole. The small hole restricts the light rays coming from the subject to a confined region, forming countless blurry image circles and a fuzzy image.

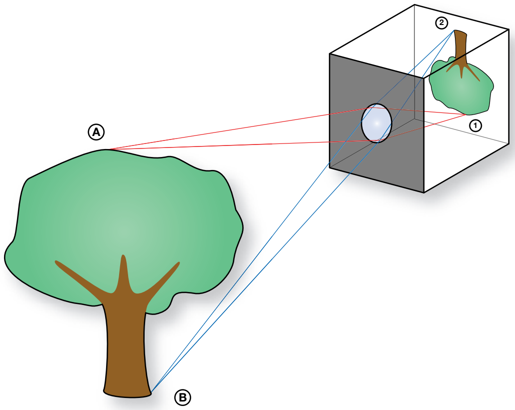


fig.3c To improve image quality, the pinhole is replaced by a lens. It converges several light rays from the same subject point into one focused image point. This makes for a sharper and brighter image than a pinhole can possibly provide.

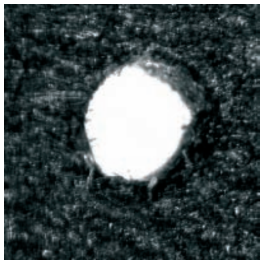


fig.4a (far left) Simply forcing a needle through a piece of cardboard will result in a workable pinhole, but the rough edge degrades image clarity.

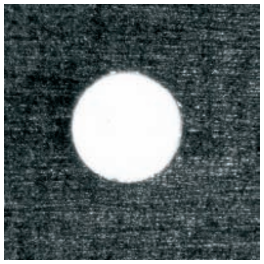


fig.4b (left) A laser-cut pinhole, with a particularly smooth perimeter, gives the best possible image quality.

For the purpose of investigating general image formation, we can safely assume that every point of an illuminated subject emits or reflects light in multiple directions. Simply holding up a card in front of the subject is not sufficient to create an image on the card, because every point on the card receives light rays from numerous points on the subject (see fig.3a). Successful image formation requires a more structured approach of correlating subject with image points.

The simplest arrangement for image formation is achieved by placing a flat opaque object, containing a tiny pin-sized hole, between the subject and the card (see fig.3b). The opaque panel blocks all light rays coming from the subject with the exception of the few entering through the pinhole. The hole is small enough to restrict the image points on the card to light rays coming from a confined region of the subject, forming countless blurry image circles, which together form a dim fuzzy image. This way, compromised image formation is possible, because every potential image point receives light rays only from a limited number of subject points.

As we can see, expensive optics are not essential to the image-forming process, but to improve image quality beyond the pinhole, the light-restricting opening must be replaced by a convex lens. The lens converges several light rays from the same subject point into one focused image point through refraction (see fig.3c). This makes for a sharper and brighter image than a pinhole can possibly provide. High-quality image formation is only possible with a lens, where every potential image point receives light rays exclusively from its corresponding subject point. Nevertheless, pinhole photography offers a subtle beauty, which is difficult to achieve otherwise and, therefore, makes exploration and optimization of this fascinating field of photography worthwhile.

## Making Your Own Pinhole Camera

The first step in building a pinhole camera is to create the pinhole itself. A high-quality pinhole is accurate in diameter and has a smooth perimeter for superior image clarity. The smoother the edge of the pinhole is, the sharper the resulting pinhole image will be. You can buy a pinhole or make one yourself.

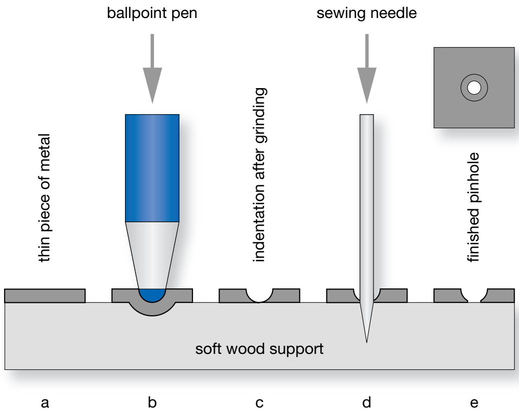
Several suppliers of optical and scientific products sell laser-cut pinholes, which are typically drilled into thin brass foil. Professionally made, laser-cut pinholes do not cost a lot, which makes them the best choice, because they are also extremely precise in diameter and have an exceptionally smooth edge (fig.4b). Nevertheless, if you are in a rush, or just want to experiment with a pinhole, you can simply take a pushpin or sewing needle and force it through a piece of black cardboard (fig.4a). This will make for a workable pinhole, but don't expect an optical miracle, because the rough edge will degrade image quality significantly.

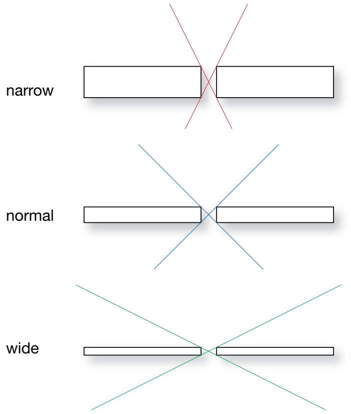
If you aim for more accuracy, consider the following work instructions, illustrated in fig.5. This will not provide you with a pinhole of ultimate precision, but with a bit of practice and the right materials, a good-quality pinhole can be made within a few minutes.

1. Use scissors to cut a piece of metal from brass foil, or an aluminum can, roughly 15x15 mm in size.
2. Place the metal flat onto a soft wood support, and firmly press a ballpoint pen into the center of the square, creating a clearly visible indentation.
3. Turn the metal over, and use fine sandpaper to thin away the bump without penetrating the metal.
4. Create the pinhole by pushing a needle through the center of the indentation, and gently reinsert the needle from the other side to smooth the edge.

fig.5a (below left) With a little bit of practice and the right materials, a good-quality pinhole can be made in a few minutes.

fig.5b (below) The pinhole material thickness limits the angle of coverage. Thick materials may reduce the angle of view, and the pinhole will no longer fill the entire negative format.





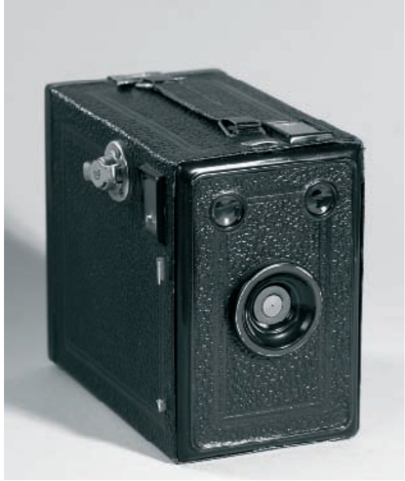


fig.6 Old medium-format camera bodies make perfect pinhole cameras. This shows a well-kept 6x9 box camera from around 1930 after the conversion.

The pinhole material thickness is of some consequence to the pinhole image, because it limits the angle of coverage. A thickness of about 0.1 mm is ideal, because it provides an angle of over 125°. Thicker materials may reduce the angle of view, and the pinhole will no longer fill the entire negative format (see fig.5b).

It is a good idea to measure the pinhole diameter before the pinhole is mounted to the camera body. It is difficult to measure afterwards, and without knowing the size of the aperture, we cannot accurately determine the working f/stop of the pinhole camera. Unless you have access to a microscope with measuring capability, simply magnify the pinhole by any available means. Use a slide projector, the darkroom enlarger or a scanner to perform this task. First, prepare a measurement sample, for example two lines, known to be 20 mm apart, and enlarge or scan this sample to determine the magnification factor. Finally, enlarge or scan the pinhole at the same magnification, measure the projection or the scan and calculate the actual diameter of the pinhole. The working f/stop of the pinhole (N) is given by:

$$N = \frac{f}{d}$$

where ‘d’ is the diameter of the pinhole, and ‘f’ is the focal length of the pinhole, which is the distance between the pinhole and the film plane, assuming that a pinhole camera is always focused at infinity.

Almost any container can be turned into a pinhole camera body as long as it is absolutely light tight. Popular items include cardboard or metal boxes of all sizes, as well as cylindrical storage containers for food, chemicals or rolls of film. Everything from 35mm film canisters to full-size delivery vans has been converted to portable pinhole cameras. Best suited, and far more practical, are old camera bodies. They are already designed to safely hold and transport film, and with the exception of view cameras, most of them offer some kind of viewfinder to compose the image and a shutter to control the exposure.

Fig.2 shows a pinhole image that was taken with a self-made 11x14-inch large-format view camera. It takes minimal effort to convert a view camera into a pinhole camera. Temporarily mounting a pinhole into an empty lens plate is all one has to do to finish the conversion. This small endeavor is rewarded with large negatives and pinhole images of surprising detail and clarity, because the maximum possible resolution with contact-printed pinhole images (see fig.14) approaches the resolving power of standard human vision, which is around 7 lp/mm.

Medium-format box cameras offer an opportunity for a more permanent pinhole conversion. Old medium-format box cameras are available in abundance on the used-camera market and can be obtained for little money. However, be certain to hunt for a model that works with the common 120-film format. This format was introduced in 1901 by Kodak for their Brownie No.2 and is still manufactured today, because it is used in all modern medium format cameras. Fig.6 shows my medium-format pinhole camera, based on a well-kept Balda Poka, which was made in Germany around 1930. I paid less than $15 for it in an internet auction. The simple meniscus lens was removed and replaced with a 0.38mm laser-cut pinhole. This diameter is ideal for the 6x9 negative format and the 105mm focal length. The working aperture computes to f/278 or f/256 and a 1/3 stop. The shutter has two settings, 1/30 s and ‘B’. For the long exposures, which are typical for the small apertures in pinhole photography, I use the ‘B’ setting exclusively and chose to keep the shutter open by securing the release lever with a rubber band.

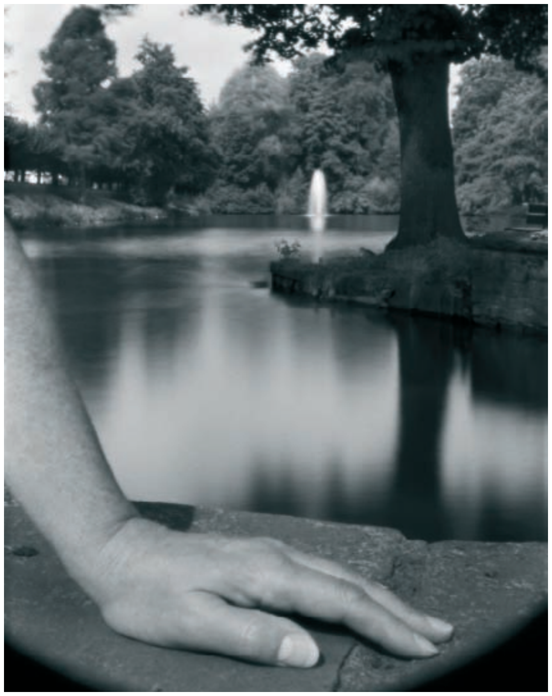


fig.7 (far right) Pinhole images have an almost infinite depth of field combined with beautiful image softness. This image softness is partially caused by diffraction but also by motion blur during long exposure times, which are rather common for pinhole photography.

The simple snapshot in fig.7, which was taken with the converted medium-format camera in fig.6, illustrates the almost endless depth of field in pinhole photography. When selecting a camera body for a pinhole conversion, be aware that many old medium-format cameras have a small red window at the back. This window is part of the manual film advance system and is provided to identify the current negative frame. The 120 roll-film format has the frame numbers of all popular medium negative formats printed on the outside of the backing paper, and they can be seen through the window. To protect the film from harmful light entering through the window, it is made of red-tinted glass or plastic. This protection works well for orthochromatic films but is not a reliable safeguard for modern panchromatic films. Before you load the camera with panchromatic film, cover the red window with a piece of black tape from the outside. Whenever you need to advance the film, shade the window with one hand and carefully pull the tape aside with the other. Then, advance the film to the next frame and quickly cover the red window with the tape again.

Analog or digital small-format SLRs are easily converted to sophisticated pinhole cameras by sacrificing an opaque body cap. The distance from the camera's lens mount flange to the film or focal plane is, therefore, an approximate measure for the focal length of the pinhole. Drill a hole into the center of the body cap, and cover it by taping an appropriate pinhole to the back (fig.8). Keep the modified cap in the camera bag for quick conversions between lens and pinhole imaging.

As with lens-based images, the quality of pinhole images increases with negative size. This may be of some consequence for images that mainly require almost endless depth of field. Nonetheless, it is important to realize that the beauty of pinhole images is largely based on their diffraction-limited performance. The inherent fuzziness makes pinhole photography perfectly suited for all those images where the subject will benefit from a little softness or romantic mystery. If pinhole images were perfectly sharp, there would be little reason to make them.

## The Optimal Pinhole Diameter

Realizing that pinhole images can never be perfectly sharp has not stopped photographers from seeking to optimize the quality of pinhole images and searching for the optimal pinhole diameter (fig.8). The image clarity of lens-based photography is limited by lens aberrations and diffraction. Closing the aperture reduces lens aberrations significantly but slowly increases the degrading influence of diffraction. This improves the overall image sharpness up to a point, but with decreasing apertures, diffraction eventually becomes the only limiting factor of image clarity. Obviously, a lens-less pinhole does not suffer from lens aberrations, but the image clarity of pinhole photography is limited considerably by diffraction.

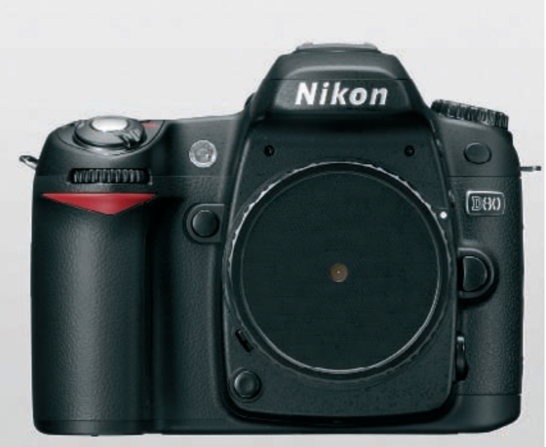


fig.8 Analog or digital SLRs are easily converted to sophisticated pinhole cameras by drilling a hole into a spare body cap and covering it with a pinhole plate.

Simple geometric optics dictate that the optimal pinhole is as small as possible, because the smaller the hole, the smaller the fuzzy image circles are (see fig.3b), and the sharper the pinhole image will be. However, this ignores the influence of diffraction, which causes the light to spread, as it passes through the narrow aperture, and increases the size of the fuzzy image circles. Diffraction optics dictate that the pinhole is as large as possible to minimize light spreading. As a consequence, the ideal pinhole diameter is as small as possible and as large as necessary.

In 1857, Prof. Joseph Petzval was apparently the first to find a mathematical equation to determine the optimal pinhole diameter. Disagreeing with his proposal, Lord Rayleigh published a competing formula in 1891, which gave a much larger diameter, as did William Abney in 1895 with yet another equation. All three attempts were based on geometric optics, but no consensus was reached among photographers as to which was the 'true' optimal pinhole diameter. More equations, this time based mainly on empirical

fig.9 Most equations to calculate the optimal pinhole diameter (d) follow the following format:

$$d = k \cdot \sqrt{\lambda \cdot f}$$

where '$\lambda$' is the wavelength of light, 'f' is the focal length of the pinhole, and 'k' is a constant value, typically between 1 and 2.

fig.10 The optimal pinhole diameter (d) to optimize image sharpness is derived from the Airy disc by:

$$d = 2.44 \cdot \lambda \cdot N$$

$$d = 2.44 \cdot \lambda \cdot \frac{f}{d}$$

$$d^2 = 2.44 \cdot \lambda \cdot f$$

$$d = \sqrt{2.44 \cdot \lambda \cdot f}$$

where 'λ' is the wavelength of light, 'N' is the pinhole aperture in f/stops, and 'f' is the focal length of the pinhole.

studies, followed until well into the 20th century. Many equations performed well enough to find enthusiastic followers, making it even more difficult to reach consensus on one optimal pinhole diameter. In retrospect, it seems like a twist of fate that Lord Rayleigh did not consider the research on diffraction by Sir George Airy from 1830, or his own diffraction criterion, which he published almost 20 years before offering his pinhole equation. Because, with his in-depth knowledge of diffraction and photography, he held the key to finding the ideal pinhole diameter, which everyone can agree to.

Remember that diffraction optics dictate that the pinhole is as large as possible to minimize light spreading, and that geometric optics dictate that an ideal pinhole is as small as possible to optimize image clarity. Considering the Airy disc and the Rayleigh criterion leads us to two theorems for an ideal pinhole diameter and suggests that there may be more than one right answer.

1. The smallest pinhole possible is based on the Airy disc to optimize image sharpness.

$$d = \sqrt{2.44 \cdot \lambda \cdot f}$$

2. The largest pinhole necessary satisfies the Rayleigh criterion to optimize image resolution.

$$d = \sqrt{3.66 \cdot \lambda \cdot f}$$

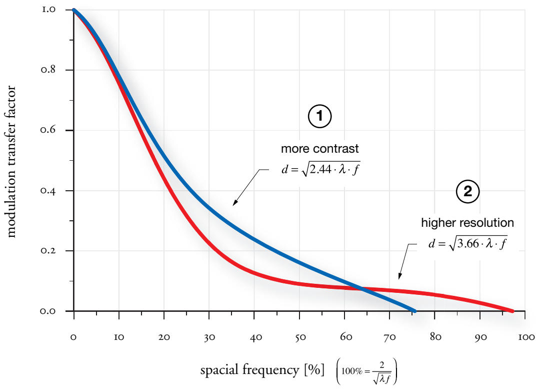
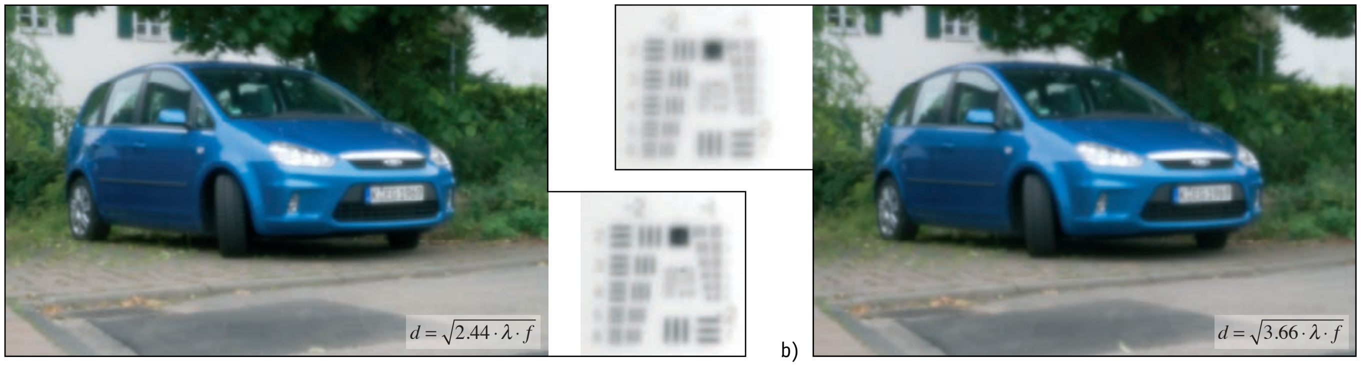


fig.11 The MTF graph compares the performance of two pinhole diameters. One offers more contrast and perceived sharpness, while the other provides more detail and resolution. (MTF data courtesy of Kjell Carlsson)

Both equations are derived, as in the example shown in fig.10, from either the Airy disc or the Rayleigh criterion. Infinity focus is assumed for both, which in reality means that they provide a depth of field from the hyperfocal distance to infinity. In both equations, the pinhole diameter is a function of the wavelength of light and the focal length of the pinhole, but a different numerical constant is used in each formula.

In 2004, Kjell Carlsson of the Royal Institute of Technology in Stockholm, Sweden conducted an evaluation of a variety of pinhole sizes. Unique to his approach was the fact that he stayed clear of subjectively comparing photographs. Instead, he computed MTF data for a number of different pinhole diameters and compared their MTF graphs. Fig.11 shows an example comparing the two proposed pinhole apertures. The diameter of equation (1) is derived from the Airy disc, and the diameter of equation (2) is based on the Rayleigh criterion. The comparison illustrates the

fig.12a-b (below) The test images in a) were taken with a small pinhole, based on the Airy disc, and the images in b) with a large pinhole, based on the Rayleigh criterion. The small pinhole in a) offers more contrast, while the large pinhole in b) provides more resolution. Most observers, however, perceive the high-contrast images on the left as being sharper of the two sets.


$d = \sqrt{2.44 \cdot \lambda \cdot f}$
$d = \sqrt{3.66 \cdot \lambda \cdot f}$

a)

b)

performance difference of the two formulas, but it also reveals why an agreement for the optimal pinhole diameter was so difficult to achieve. Equation (1) offers more contrast and perceived sharpness, while equation (2) provides more detail and resolution.

A set of test images in fig.12 verifies the theoretical evaluation. A small-format digital SLR (see fig.8) was equipped with a small pinhole, based on the Airy disc (0.25 mm), to create the images in fig.12a, and a large pinhole, based on the Rayleigh criterion (0.30 mm), to create the images in fig.12b. The images in fig.12a have more contrast and appear to be overall sharper than the images in fig.12b, as seen in the license plates, while the images in fig.12b have more resolution, as the bar charts reveal. Confusingly, this leaves us with two options for an optimal pinhole diameter, one for contrast and one for resolution. It is necessary to decide which of the two we want to optimize, before we agree to just one optimal pinhole diameter.

The quest for the optimal pinhole diameter is generally fueled by the desire to create the sharpest pinhole image possible. Contrast and resolution are both aspects of sharpness, but as demonstrated in fig.12, human perception typically prefers high-contrast images to high-resolution images. Consequently, unless resolution is more important than perceived sharpness, my proposal for the optimal pinhole diameter (d) is based on George Airy's diffraction-limited disc:

$$d = \sqrt{2.44 \cdot \lambda \cdot f}$$

or in the more conventional format:

$$d = 1.56 \cdot \sqrt{\lambda \cdot f}$$

where 'λ' is the wavelength of light, and 'f' is the focal length of the pinhole. A common value for the wavelength of light is 555 nm (0.000555 mm), which is the eye's sensitivity peak and an appropriate value for standard pictorial photography. For infrared photography, use the film's spectral sensitivity instead.

The graph in fig.13 shows how the optimal pinhole diameter increases with focal length, and the table in fig.14 provides useful data for some popular focal lengths to help with the design, exposure and composition of pinhole images.

## Pinhole Aperture, Exposure and Focus

As we saw in fig.5a, regular sewing needles are convenient tools to create quality pinholes. Since the beginning of the 19th century, needle sizes are denoted by numbers, and the convention is that the thickness of a needle increases as its number decreases. In other words, the higher the needle size number, the thinner the needle. Fig.14 identifies the most appropriate needle size to create a popular pinhole diameter.

Fig.14 also shows the approximate pinhole aperture in f/stops with 1/3-stop accuracy. Use this aperture for all exposure calculations or measurements, and don't forget to consider film reciprocity, as exposure times are likely long enough for reciprocity to have a significant effect. Most general-purpose lightmeters do not have aperture settings beyond f/64. This makes their application somewhat cumbersome for pinhole photography, where apertures of f/256 and smaller are the norm. However, fig.14 provides exposure compensation for all f/stops in relation to f/64. Set your lightmeter to f/64 to determine the exposure, and extend the exposure time according to the indicated f/64 compensation for your pinhole aperture. You will find a special pinhole dial in the appendix under 'Tables and Templates' to simplify this task.

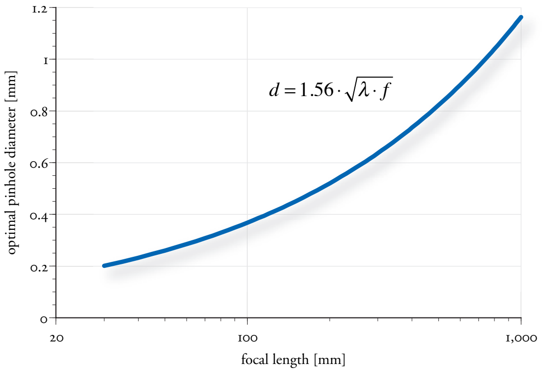


fig.13 The optimal pinhole diameter for perceived sharpness is based on the equation for the Airy disc.

| focal length [mm] | pinhole diameter [mm] | needle size | aperture | f/64 rel exp [stops] | max resolution [lp/mm] | hyperfocal distance [mm] | pinhole extension [mm] |
|---|---|---|---|---|---|---|---|
| 35 | 0.22 | - | f/128 •• | +2 •• | 9.2 | 105 | 18 |
| 45 | 0.25 | 15 | f/180 | +3 | 8.1 | 135 | 23 |
| 55 | 0.27 | 14 | f/180 • | +3 • | 7.3 | 165 | 28 |
| 75 | 0.32 | 13 | f/180 •• | +3 •• | 6.3 | 225 | 38 |
| 90 | 0.35 | 12 | f/256 | +4 | 5.7 | 270 | 45 |
| 105 | 0.38 | 11 | f/256 • | +4 • | 5.3 | 315 | 53 |
| 135 | 0.43 | 11 | f/256 •• | +4 •• | 4.7 | 405 | 68 |
| 150 | 0.45 | 10 | f/256 •• | +4 •• | 4.4 | 450 | 75 |
| 180 | 0.49 | 10 | f/360 | +5 | 4.1 | 540 | 90 |
| 210 | 0.53 | 9 | f/360 • | +5 • | 3.8 | 630 | 105 |
| 300 | 0.64 | 8 | f/360 •• | +5 •• | 3.1 | 900 | 150 |
| 450 | 0.78 | 6 | f/512 • | +6 • | 2.6 | 1,350 | 225 |
| 600 | 0.90 | 4 | f/512 •• | +6 •• | 2.2 | 1,800 | 300 |
| 800 | 1.04 | 3 | f/720 | +7 | 1.9 | 2,400 | 400 |

fig.14 This table provides useful data for some popular focal lengths to help with the design, exposure and composition of pinhole images.

a) optimal pinhole diameter
b) needle number to make pinhole
c) working aperture in 1/3 stops
d) exposure compensation relative to f/64 exposure measurement
e) maximum pinhole resolution
f) hyperfocal distance
g) pinhole extension required to focus at hyperfocal distance

Most pinhole cameras do not provide any type of focus adjustment, and therefore, a pinhole camera is always focused at infinity. This means that the depth of field extends from the hyperfocal distance to infinity, and the hyperfocal distance is the front focus limit. A look at the hyperfocal distance in fig.14 demystifies why pinhole cameras are considered to have almost endless depth of field. At f/256 pinhole focus amazingly extends from 270 mm to infinity.

Depth of field can be extended even further if the pinhole camera provides some kind of a focus adjustment, as it would in a view camera conversion. Maximum depth of field is obtained when the pinhole

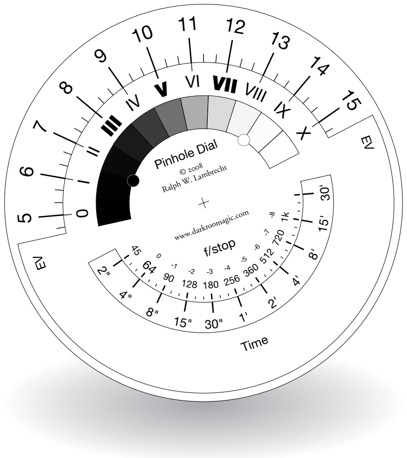


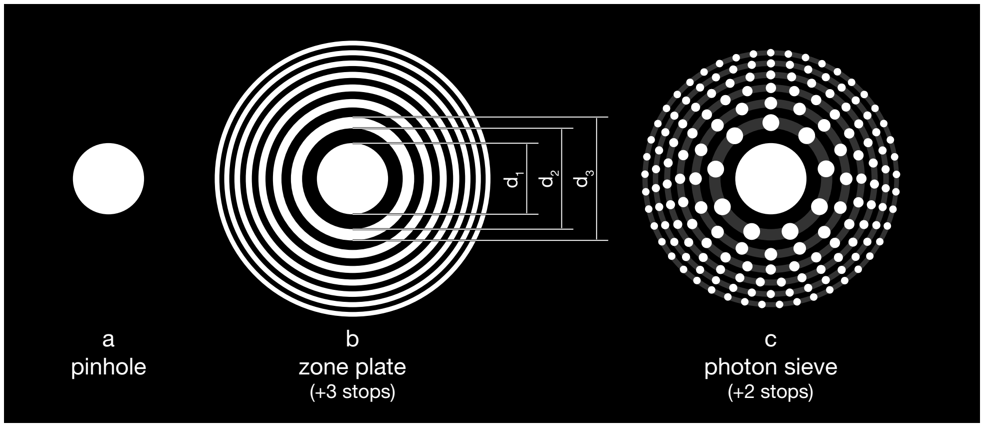
fig.15 In the chapter 'How to Build and Use a Zone Dial', a useful Zone System dial is presented for general exposures. Pinhole photographers will be happy to know that they can find a special pinhole version in the appendix under 'Tables and Templates'.

is focused at the hyperfocal distance, in which case, depth of field starts at half the hyperfocal distance and extends to infinity. Of course, visual focusing is impossible with small pinhole apertures and the dim images they create. That is why the last column in fig.14 provides a dimension for the pinhole extension. Extend the pinhole-to-film distance by this amount in order to focus the image at the hyperfocal distance. As with all close-up photography, moving the pinhole closer to the subject moves it away from the film, which reduces film illumination. This must be compensated by an increase in exposure time, and in case of the optimal pinhole diameter, by an exposure increase of 1 1/6-stop for hyperfocal focusing.

## Pinhole Alternatives

There is hardly another field in photography more inviting to experimentation than pinhole photography, and modifying the pinhole aperture is a creative method to produce endless possibilities for image alternatives. If the aim is image clarity, a plain circular hole of optimal diameter is hard to beat, but if you like to explore unconventional substitutes, try apertures of all shapes, including horizontal, vertical and wavy slots. More technical aperture alternatives for pinholes are diffraction zone plates and photon sieves.

Lenses produce images through refraction; pinholes produce images through diffraction. With zone plates and photon sieves (fig.16), photographers take full advantage of diffraction by creating apertures that simulate the Airy diffraction pattern. Both have larger apertures and require less exposure than plain pinholes but produce fuzzier images with less depth of field.



a
pinhole

b
zone plate
(+3 stops)

c
photon sieve
(+2 stops)

fig.16 Diffraction zone plates and photon sieves are alternatives to a plain pinhole. They have larger apertures and require less exposure but produce fuzzier images with less depth of field.

A zone plate (fig.16b) consists of a center hole, which has the same diameter as the optimal pinhole, and an arbitrary number of concentric rings or zones, alternating between opaque and transparent. The outer diameter for each zone ($d_n$) is given by:

$$d_n = 1.56 \cdot \sqrt{\lambda \cdot f \cdot n}$$

where 'λ' is the wavelength of light, 'f' is the focal length of the pinhole, and 'n' is the sequential number of the zone. It is important to note that each zone, whether opaque or transparent, has the same surface area as the center pinhole. This means that a zone plate with seven additional transparent zones has eight times the light-gathering power of the pinhole alone, which is equivalent to an aperture improvement of +3 stops.

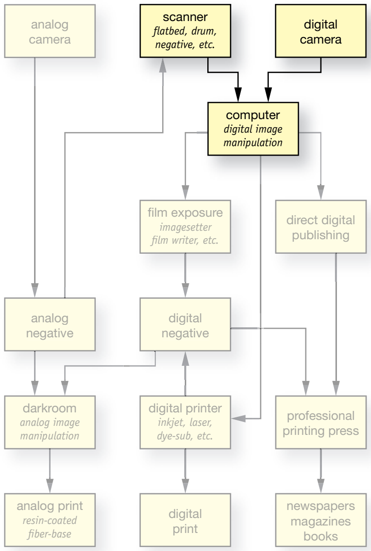
Another pinhole alternative is a multi-pinhole pattern, also called mega-pinhole or photon sieve. Instead of using the entire ring of a diffraction zone, as in the zone plate, an arbitrary number of small pinholes are distributed along the theoretical zones of the photon sieve, forming a hole pattern for each diffraction zone. While the diffraction zones become thinner and thinner as they ripple away from the center pinhole, the pattern holes become smaller and smaller towards the outside of the photon sieve. The design in fig.16c distributes just enough holes in each zone to equal half the surface area of the center pinhole for each hole pattern. This means that a photon sieve with six additional hole patterns has four times the light-gathering power of a single pinhole alone. This is equivalent to an aperture improvement of +2 stops.

Of course, it's impossible to cut or drill zone plates and photon sieves like pinholes. The best way to make them is to create an enlarged, tone-reversed drawing of the design and photograph it onto high-contrast B&W film thus reducing it to the right size. Two design patterns are available in the appendix under 'Tables and Templates'. The trade-off for increased light-gathering power with zone plates and photon sieves is a reduced depth of field and a loss of image quality, which is a result of larger apertures and less than perfectly transparent materials. Nevertheless, for many photographers, the unique image characteristics of these special apertures more than make up for all their disadvantages. The same is true for pinhole images in general. They are well worth a try.

# Basics of Digital Capture

## The essential elements of digital imaging, quality and archiving

This book predominantly covers the details of traditional darkroom work, because we believe that analog photography provides the most valuable final product possible: a silver-gelatin print, properly processed to archival standards. With the recent advent of digital imaging, however, even the most sophisticated image manipulation techniques are readily available to anyone with access to a powerful computer and specialized image software. Digital image manipulation is often easier and more powerful than its darkroom counterpart and typically delivers seamless results in less time. By combining analog photography and digital imaging, these sophisticated options also become available to the analog darkroom enthusiast. This chapter is an introduction to digital imaging in order to take advantage of these cross-over technologies, some of which are presented throughout the rest of the book. Digital imaging is a vast subject, which has already filled many books on its own. Consequently, we will not get into the intricacies of digital image manipulation, but we will introduce essential digital elements and discuss choices that have a direct bearing on protecting digitally stored image data and achieving the best image quality possible.


analog camera
scanner
flatbed, drum, negative, etc.
digital camera
computer
digital image manipulation
film exposure
imagesetter film writer, etc.
direct digital publishing
analog negative
digital negative
darkroom
analog image manipulation
digital printer
inkjet, laser, dye-sub, etc.
professional printing press
analog print
resin-coated fiber-base
digital print
newspapers magazines books

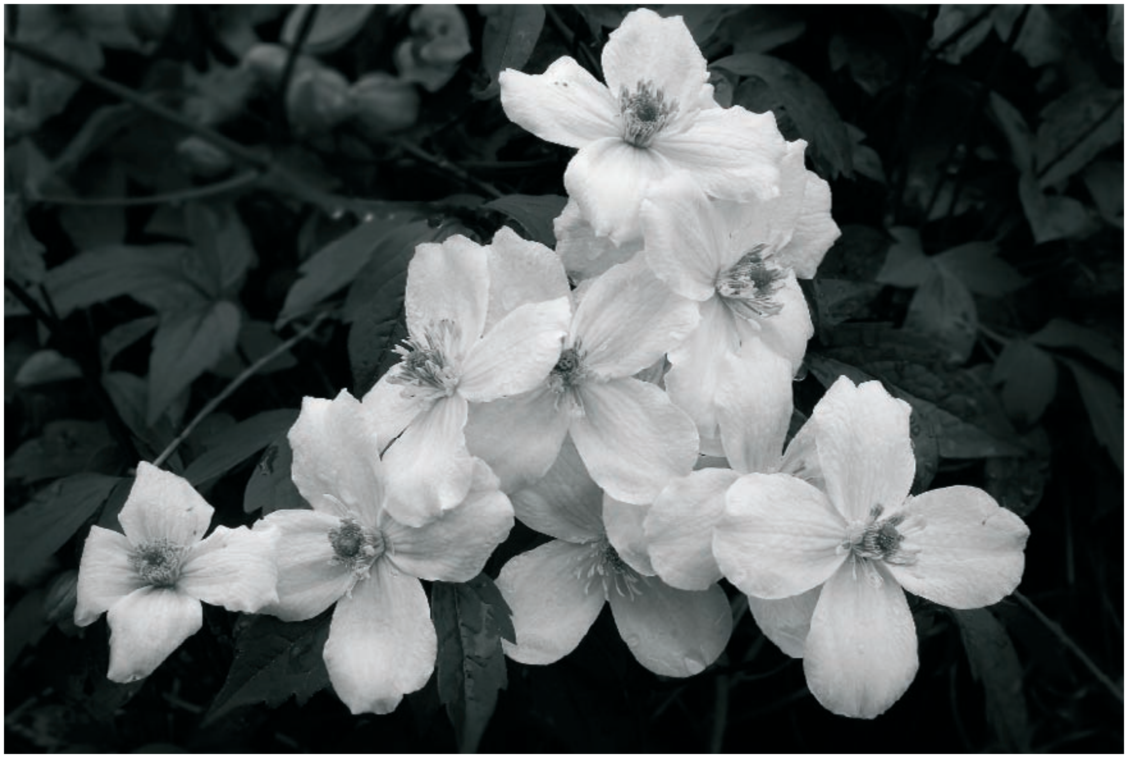


fig.1 The color original of this image was taken with a digital SLR and converted to monochrome through imaging software. To ensure these delicate white flowers show plenty of detail, the image was taken in diffuse sunlight with a small degree of underexposure and using a tripod. An aperture of f/11 was used to ensure all the petals were in focus, though at this small aperture setting, the image quality was already starting to be limited by diffraction. Digital equivalents of traditional darkroom manipulations were used to suppress edge detail and lift the tonal values.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50020-X

Canon
EOS 5D
CANON EF LENS
24-105mm 1:4

fig.2 (right) The Canon EOS 5D is one of the world's first full-frame digital SLRs, featuring 12.8 million effective pixels at a pixel size of 8 μm (microns).
(image copyright Canon, Inc.)

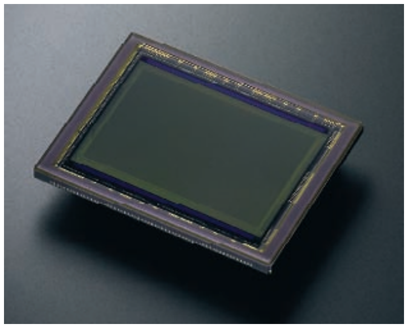


fig.3 (top) The full-frame sensor of a Nikon D3x provides 24.5 million pixels at a size of 6 microns each.
(image copyright Nikon, Inc.)

## Digital Camera Sensors

Because film is a relatively cheap consumable, we tend to forget the amazing technology behind it. Simply put, film is a plastic strip, coated with a thin layer of gelatin and loaded with light-sensitive silver salts. Understanding the boundaries of this remarkable commodity is the key to its full exploitation. Similarly, in the fast moving world of digital imaging, it is essential to understand the basic function, a few essentials and the physical limitations involved with digital sensor design to make use of their full potential. For both film and digital systems, there is no magic formula. In spite of continuous technological advancement in digital imaging, there are still considerable trade-offs between cost and image quality, not to mention the ultimate limits placed on digital capture by the laws of physics.

### Sensor Elements, Pixels and Resolution

A simple photoelectric sensor transforms light energy into an electrical signal. To make this process useful for digital imaging, the analog signal is converted into a numeric value using an analog-to-digital converter, often called A/D converter or simply ADC.

To record an entire image digitally, one needs a closely packed array of sensor elements, whose signals are converted by the ADC into an orderly sequence of numbers. During the camera exposure, each sensor element collects and stores the energy from the photons they receive. The camera electronics then measure the captured energy level for each sensor element and convert it, with the help of the ADC, into a matrix of distinct intensity levels (fig.4). In this way, digital cameras scan or sample the image in fine increments and record them as image detail. Generally speaking, the finer the sample increments are, the more realistic the final digital image appears to the viewer. Image resolution must be fine enough to be unidentifiable as a matrix of pixels when the final print is observed from a normal viewing distance.

Unlike film, which is a homogenous photosensitive surface (see fig.5), digital camera sensors do not actually have sensor elements covering the entire surface area of the array. In some cases, they cover just half

|  |  |  |  |
|---|---|---|---|
| 15 | 29 | 116 | 218 |
| 16 | 74 | 182 | 236 |
| 51 | 154 | 213 | 238 |
| 110 | 187 | 214 | 239 |

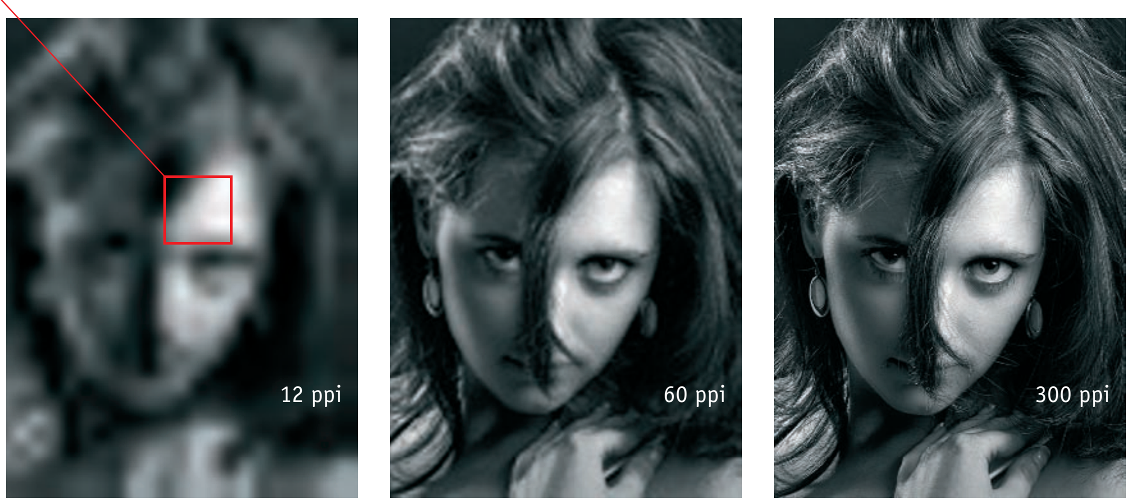


fig.4 To be useful for digital imaging, image detail must be recorded in samples small enough to be unidentifiable as a matrix of pixels when the final print is observed from a normal viewing distance. From left to right: this image was recorded to be shown at 12, 60 and 300 ppi (pixels per inch). The matrix of pixels is very obvious at 12 ppi, and from a minimum viewing distance, it is still clearly detectable at 60 ppi. At 300 ppi (equivalent to 6 lp/mm), however, the digital origin of the image is nearly concealed.

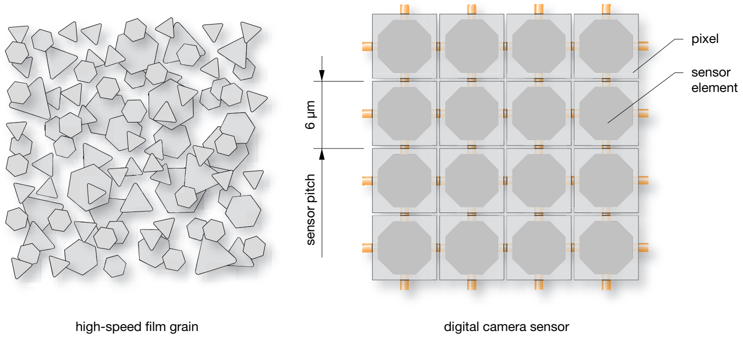


fig.5 Unlike film (left), which is a homogenous photosensitive surface, digital camera sensors (right) do not have sensor elements covering the entire surface area of the array, in order to accommodate the electronics in-between them.

the image sensor surface in order to accommodate the supporting electronics in-between them. But, discarding light energy is wasteful and forces the electronics to work with a weaker signal. Digital cameras minimize this problem by placing a microlens above each sensor element to enhance their light-gathering ability. This improves the image sensor efficiency and signal strength of each sensor element.

The sensor pitch is the physical distance between two sensor elements and is equal to the effective pixel size. Typically, current digital SLRs have an effective pixel size of about 5-8 µm (microns). Compact digital cameras and mobile phones often offer the same megapixel count but on a much smaller sensor array. As the pixel size is reduced, either as a result of the overall sensor shrinking, or from packing more pixels into the same sensor real-estate, the light gathering ability of each sensor element is also reduced. As a consequence, the sensor resolution is improved by the number of pixels, but the signal level of each sensor element is lowered. The ongoing challenge is to design image sensors with higher packing densities without compromising the optical efficiency. The current state of technology suggests that the optimum pixel size is around 7-8 microns, leading to the conclusion that better resolution and overall performance can only be achieved by increasing the sensor size, and not by reducing the pixel size.

| | **target print size [inch]** | **min image resolution [ppi]** |
|---|---|---|
| | 5x7 | 370 |
| (A4) | 8x10 | 280 |
| | 9½x12 | 230 |
| (A3) | 11x14 | 200 |
| | 12x16 | 180 |
| (A2) | 16x20 | 140 |

Nevertheless, the trend in digital sensor design is to increase the pixel count. Some increases are more meaningful than others. As long as the size of the image sensors remains unchanged, every doubling of the amount of pixels increases the sensor resolution by more than 40%. A change from 10 to 12 megapixels increases resolution by less than 10%.

To satisfy the criteria of standard image resolution, one needs at least 370-image ppi (pixels per inch) for a 5x7-inch print, because a print this small is typically observed from the closest possible viewing distance. As print sizes and viewing distances increase, resolution requirements are reduced proportionally. A 16x20-inch print needs as little as 140 ppi to look convincingly realistic, and a billboard across the road may need no more than 12 ppi to conceal its pixelated origin.

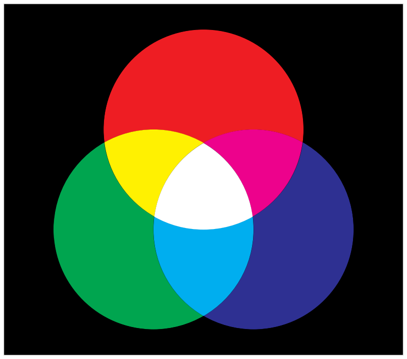


fig.6 An additive color system starts with no light (black) and adds the three primary colors Red, Green and Blue (RGB) in varying amounts to produce any color of the visible spectrum. Combining all primary colors in equal intensities produces white.

**Color Perception**

Image sensors are essentially panchromatic, although they exhibit a varying sensitivity to different wavelengths of light, just as film does. Color science differentiates between additive and subtractive color systems. An additive color system starts with no light (black) and adds the three primary colors Red, Green and Blue (RGB) in varying amounts to produce any color possible in the visible spectrum (fig.6). Combining all primary colors in equal intensities produces white. This creates the opportunity to measure image color by combining the results of three sensor elements, which have been made color selective through individual color filters.

It may appear that distributing image color measurement to three different sensor elements comes at the expense of reduced image resolution. In nearly all digital cameras, this problem is solved through an ingenious pattern of color filters (fig.7) called a 'Bayer array'. In this array, a group of four pixels, each containing one red, two green and

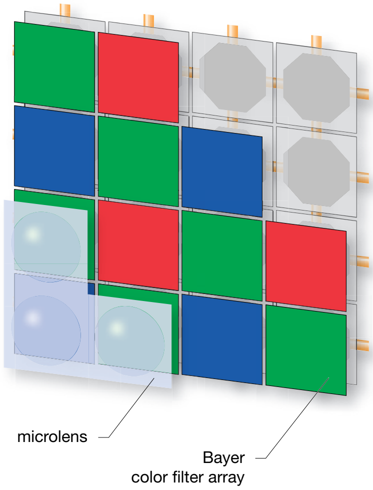


fig.7 The Bayer array takes into account that human vision is particularly sensitive to green light, and features twice as many green filters, as red and blue filters. Each pixel captures only one primary color, but 'true' color is calculated from neighboring pixels.

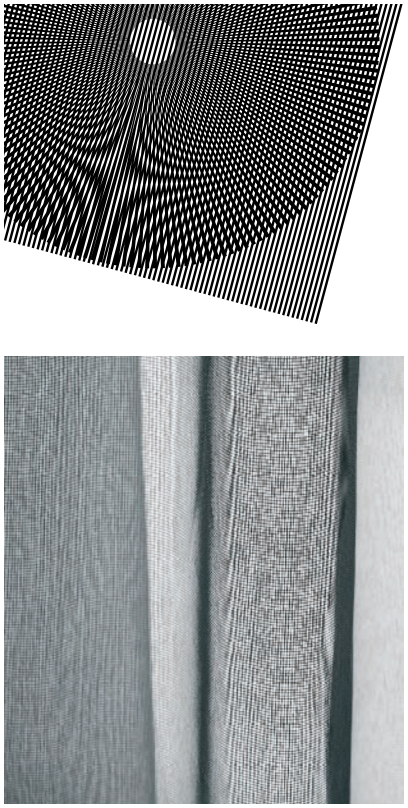


fig.8 When two regular patterns of closely spaced lines are superimposed (top), they show a pattern of irregular wavy lines, called moiré. The image sensor's pixel pattern, in combination with certain subjects (bottom), may create moiré lines in digital photographs.

one blue filter, is assigned to collect one full piece of color information. This pattern takes into account that human vision is particularly sensitive to green light, and features twice as many green filters as red and blue filters. Each filter is located directly on top of a sensor element, so that each pixel captures only one color channel. The missing channels for each pixel are calculated from neighboring pixels through a process called 'demosaicing'. The color image is recorded in the form of an RGB file, which is made up of three color channels and contains 'true' color information for each pixel on the image sensor.

### Moiré

When two regular patterns of closely spaced lines are superimposed, they create another pattern of irregular wavy lines, called moiré (fig.8). The image sensor's closely spaced array of pixels is organized in a regular pattern. If the subject to be photographed also contains a regular, closely spaced pattern, then disturbing moiré lines may be observed in the picture. Common subject details, such as the shingles on a roof, a distant fence or some fabrics, for example window curtains, are prone to this effect. To minimize the problem, many cameras are equipped with a mildly diffusing moiré filter in front of the sensor.

### Noise

Ultimately, the quality of any device is limited by the small difference between the signal transmitted and the signal received. The words heard over the phone are never quite as clear as the words spoken at the other end. Analog and digital cameras have a similar limitation. With an analog camera, the film grain limits the level of fine subject detail the camera can capture, and the digital camera equivalent of film grain is called image noise.

Each sensor element transforms the light energy received into an electrical signal, which is converted into a numeric value by the analog-to-digital converter. If the sensor element is struck by a bright highlight, the signal is strong, and if the light was transmitted by a dim shadow detail, the signal is weak. Unfortunately, sensor technology is not perfect, and while every sensor element transforms the light energy received into a signal, it also adds some random noise or sporadic peaks. For the most part, identical light levels are transformed into slightly different signal strengths by different sensor elements, which are then converted into varying numeric values by the ADC. The result is a more or less constant image noise, which appears as random speckles on an otherwise uniform surface (fig.9).

Image noise appears predominantly in areas of low exposure and shows up most disturbingly in smooth tones. Noise is amplified with higher ISO settings and longer exposures, but is less problematic with larger sensors, because large sensors have large sensor elements that collect more light and create stronger signals than small elements. This means that the sensor noise is only a small fraction of the sensor signal. The signal-to-noise ratio (SNR) is a useful and universal method to compare the relative amounts of signal and noise in any system. High signal-to-noise ratios will have very little apparent image degradation whereas the opposite is true for low ratios. High-quality sensors aim to make the noise level insignificant with respect to the signal, so that its influence is minimal.

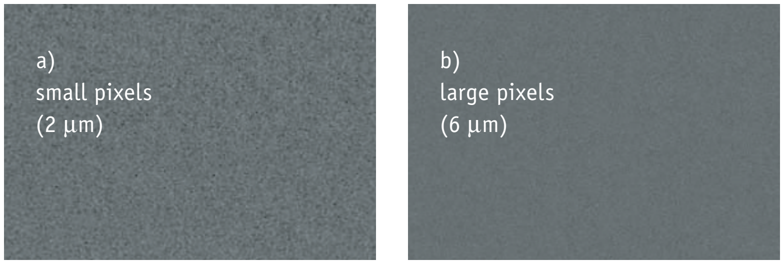


fig.9 Two images of a uniform surface were taken with a digital compact camera (left) and a professional digital SLR (right) at low light with a high ISO setting. These 300 ppi examples clearly show the advantage of larger image pixels.

### Speed

A film's ISO speed describes its sensitivity to light. Digital cameras can uniquely capture images at many different ISO speeds. This is accomplished by amplifying the sensor signal prior to the conversion into a digital number. Amplification does not improve the signal-to-noise ratio, since it amplifies the combined sensor signal and noise equally. As a consequence, camera exposures at high ISO speeds, which capture low light energy levels, will produce significant image noise. For the best image quality, one should select a low ISO value, use the optimum aperture and support the camera with a tripod.

### Depth of Field and Resolution Limits

Broadly speaking, for a given aperture, the depth of field for a lens is inversely proportional to the focal length. Therefore, optics with a short focal length offer more depth of field than longer lenses. Small camera formats require shorter focal lengths in order to provide the same angle of view than larger formats and have a larger depth of field at similar aperture. This is one reason why small digital compact cameras have such an enormous depth of field. In other words, digital cameras do not offer more depth of field than film cameras, but a small camera format offers more depth of field than a large camera format, because it typically uses lenses with shorter focal lengths.

With film cameras, image resolution is limited by lens aberrations and diffraction alone (see 'Sharpness and Depth of Field', fig.11 for details). Regular film is not a limiting factor, because the resolution potential of its fine grain is above the combined limits of aberrations and diffraction. However, with digital cameras, the resolution of the image sensor cannot be ignored. At working apertures, sensor resolution is typically the only limiting factor of digital image resolution.

As a wide-open digital camera lens is stopped down, image resolution increases at first, because lens aberrations are reduced. Image resolution peaks at an 'optimal' aperture limited by sensor resolution. Stopping the lens down further decreases image resolution again, due to the ever increasing influence of diffraction, but it requires very small apertures (f/22 or smaller) before diffraction becomes the only limiting factor of image resolution.

For any depth of field calculation this means, if the sensor resolution ($R_{digital}$) is coarser than the circle of confusion required to support the viewing conditions, the optical system is limited by the sensor, and the smallest circle of confusion ($c_{min}$) is given by:

$$c_{\min} = \frac{1}{R_{digital}}$$

As an example, if the image sensor has a pixel size of 8 microns, and at least 2.1 pixels are needed to reliably record a line pair, then sensor resolution is 60 lp/mm (1/(0.008x2.1)), and there is no need to take a smaller circle of confusion than 0.017 mm (1/60) into account, because the sensor resolution does not support it.

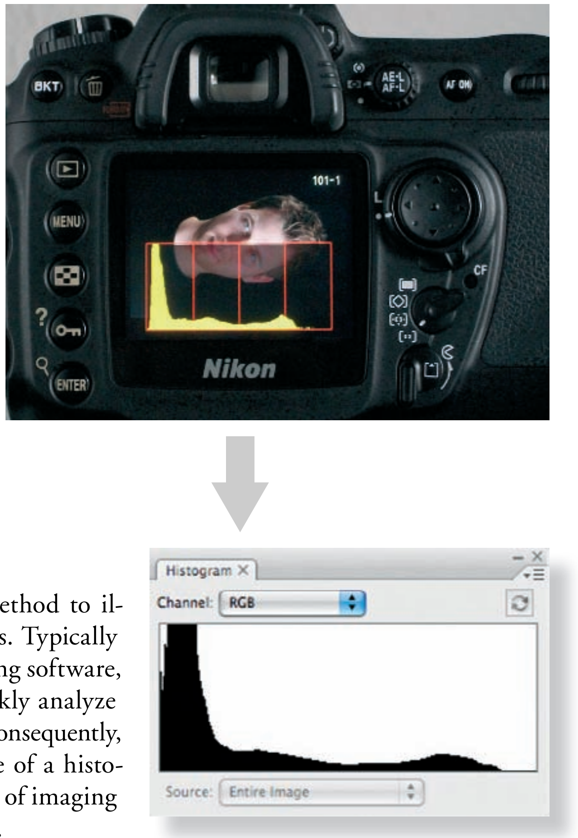
## Tonal Control

Photographers working in the digital domain enjoy a remarkable advantage to the envy of every darkroom worker. This is the ability to manipulate image tonality almost endlessly. At the simplest level of digital image manipulation, the overall contrast and tonal distribution can be averaged or adjusted to preset standards. At its most sophisticated level, digital image manipulation permits overall or local image tonality to be precisely controlled using a variety of specialized creative tools. Three tools, however, accomplish the majority of tonality control: 'histogram', 'levels' and 'curves'.

### Histogram

A histogram is an efficient graphical method to illustrate the distribution of large data sets. Typically provided with digital cameras and imaging software, the histogram is a common tool to quickly analyze the distribution of brightness values and, consequently, image tonality. Fig.10 shows an example of a histogram on a digital camera and as a feature of imaging software. Both follow the same principle.

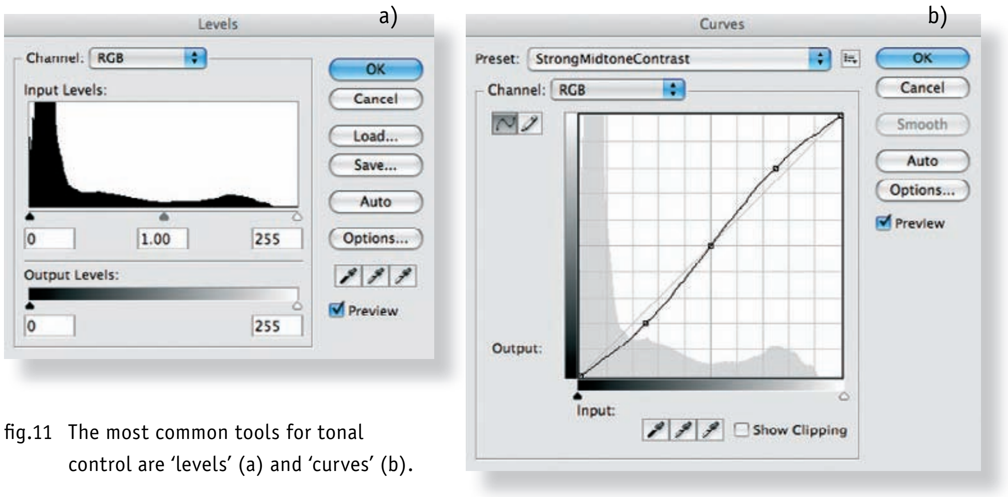
The horizontal axis represents all image tones from black (left) to white (right), and the vertical axis represents the relative amount of pixels using each tonal value. At a glance, this visual aid indicates whether an image uses the available tonal range, is generally under- or overexposed, and whether the exposure is



Channel: RGB

Source: Entire Image

fig.10 (top) The histogram, typically provided with digital cameras and imaging software, is a common tool to quickly analyze the distribution of brightness values and image tonality.



a) Levels

Channel: RGB

Input Levels: 0 1.00 255

Output Levels: 0 255

☑ Preview

b) Curves

Preset: StrongMidtoneContrast

Channel: RGB

☑ Preview

☐ Show Clipping

fig.11 The most common tools for tonal control are 'levels' (a) and 'curves' (b).

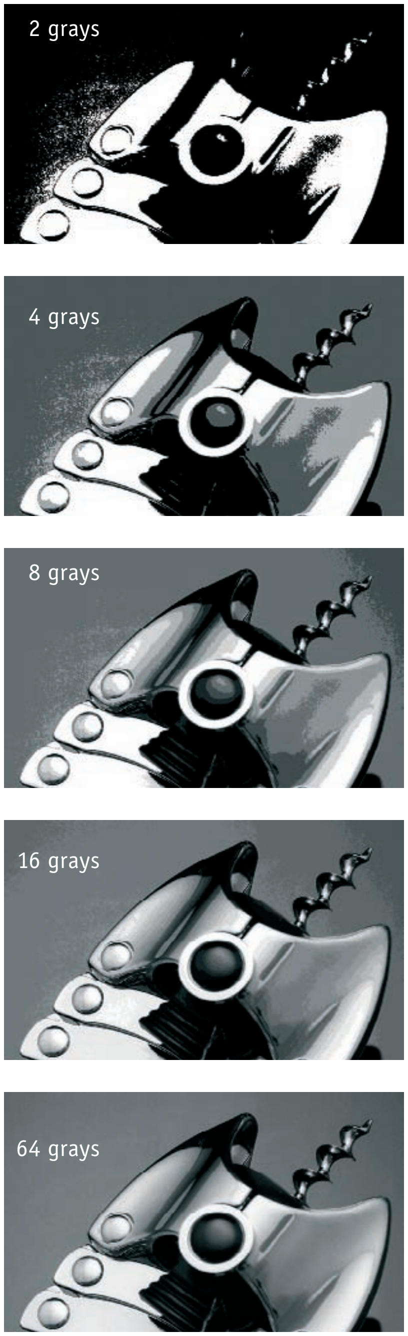


fig.12 This sequence shows how increasing bit-depth ultimately provides photo-realistic images. From top to bottom, 1, 2, 3, 4 and 6 bits per pixel allow for 2, 4, 8, 16 and 64 levels of gray.

clipped, losing essential shadow or highlight information. Ideally, the response should tail off, just before reaching the extreme ends of the scale. The histogram is often used in conjunction with tonal controls such as ‘levels’ and ‘curves’.

**Levels and Curves**

Nearly every digital image requires some change to exposure and contrast to improve tonality. The most common tonal controls are ‘levels’ and ‘curves’, which are present in all sophisticated imaging software. Of the two, ‘curves’ is the most powerful, whereas the ‘levels’ adjustment has a simpler interface and a reduced flexibility of tonal control. Either way, the effective contrast and brightness of an image is changed so that key highlight and shadow areas have the correct tonal values. This is then confirmed by placing the eyedropper tool into these key areas and reading the RGB or grayscale information at that point.

Fig.11a shows a typical ‘levels’ dialog box. It includes a histogram of the image, immediately above three sliders. The two outer sliders effectively control the shadow and highlight endpoints of the image, much like basic exposure and contrast controls in darkroom printing. Moving these sliders towards the center increases image contrast, but if they are moved into the histogram distribution, some image tones are clipped into featureless black or white. The third slider in the middle controls the tonal distribution smoothly between the endpoints, effectively lightening or darkening the midtones. The darkroom equivalent to this is more involved, because it requires switching to a different film or paper, or modified processing. If an image looks good on-screen but suffers from empty highlights and blocked shadows when printed, then moving the bottom two sliders towards the center lowers the contrast and redistributes the image tones evenly between the printable tonal extremes.

Fig.11b shows an example of the more sophisticated ‘curves’ adjustment tool. In essence, it allows the user to map any tone to any other tone using a transfer curve. In doing so, one can change exposure and contrast, or create nonlinear tonal distributions and control highlight or shadow separation at the same time. It can be used to mimic camera filters, complex darkroom techniques and much more. The example shown here includes the histogram in the background for reference and uses a gentle S-curve tonal adjustment to increase midtone contrast. The curve can be adjusted by numerical input or arbitrarily reshaping the curve with the mouse.

Both the ‘levels’ and ‘curves’ adjustments can be applied to the entire image or only to a selection. Both tools can do far more than can be explained here in a few paragraphs, and beyond this introduction comes the stony road of practice and experience.

## Bit Depth

The bit depth of an image refers to the number of binary digits that describe the brightness or color content of an image pixel. A single binary digit is either on or off, and therefore, it can represent only the numbers ‘0’ or ‘1’. A black and white image without real grays can be described by a sequence of 1-bit digits, but to record intermediary levels, more tonal resolution and more binary digits are necessary.

Fig.12 compares a sequence of images, rendered at several low bit-depths. Beyond that, an 8-bit (1 byte) grayscale image has the potential to show 256 levels of gray, and a 24-bit RGB color image, with 1 byte or 8 bits for each color channel, can show over 16 million different colors.

The camera hardware determines the maximum bit depth, which typically ranges from 8-16 bits per channel. With 16 bits per channel, more than 65,000 levels of gray and over 281 trillion different colors can be stored. This may seem a little extreme, but they have been made available for good reason.

An experienced observer with good eyesight can detect the differences between roughly 200 evenly distributed gray levels and 10 million colors. Therefore, one might think that 8-bit image data per channel is more than sufficient for quality work, but this is not the case in practice, because we like to end up with evenly distributed image tonality after all image manipulations are completed. As we will see, this requires an abundance of image data to start with.

| Bit Depth | Levels of Gray | |
|---|---|---|
| 1 bit | 2 | (black & white) |
| 2 bit | 4 | < posterization > |
| 3 bit | 8 | |
| 4 bit | 16 | |
| 5 bit | 32 | |
| 6 bit | 64 | |
| 7 bit | 128 | |
| 8 bit | 256 | (full tonal scale) |

## Posterization

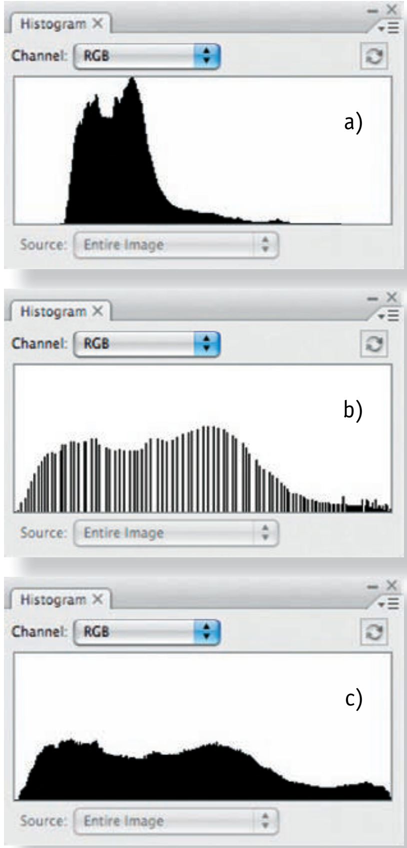
In order for a photograph to look realistic, it must have an abundance of image tones with smooth tonal gradation between them. This requires an image file with sufficient bit depth. If the bit depth is too low, smooth tonal gradation is impossible, and what was meant to be a continuous-tone image is reduced to a limited number of gray levels or colors. If overdone, the loss of image tones becomes obvious and the image starts looking like a mass-produced pop-art poster and not like a realistic photograph. At that point, the image is 'posterized', and the process of reducing the bit depth to that extreme is called posterization.

The most common cause of posterization is extreme image manipulation through software tools such as 'levels' and 'curves'. Posterization is more obvious in areas of smooth tonal transition, such as in skies, studio backgrounds, polished surfaces and smooth skin tones. These areas require delicate tones to describe them, and any decrease in bit depth can quickly have a visual impact. The best way to avoid posterization is to manipulate only 16-bit images or keep 8-bit manipulation to an absolute minimum.

A potential danger of posterization is easily detected by reviewing the image file's histogram. Fig.13a shows the histogram of an 8-bit image file, which is obviously missing most midtone and all highlight values. Fig.13b shows the histogram of the same file after the tonality was spread out, in an attempt to obtain a full tonal scale image, and several other corrections were applied to optimize image appearance. Any gap in the histogram indicates pixel values without occurrence and, consequently, missing image tones. Small gaps are not necessarily causing posterization, but larger gaps are clear warning signs of potential posterization. Fig.13b indicates that the 8-bit image file did not have enough tonal information to support such extreme manipulation. The result is a posterized image, which is missing too many tonal values.

Fig.13c shows the histogram of a file that had been identically manipulated, but this time, the original image file contained 16 bits per pixel. The resulting image is not missing any pixel values and features a smooth tonal distribution from black to white. To illustrate the effect of posterization in actual prints, fig.14 shows two examples of image manipulation applied to an 8- and 16-bit image.

Posterization may also occur after converting an image from one color space to another. For monochrome work, the effect is minimized by recording exposures in the camera's raw file format and converting them to 16-bit grayscale images before any manipulation attempt is made. If one must work with an 8-bit image, start by converting it to a 16-bit grayscale image and apply a minimal amount of Gaussian blur. This minimizes the possibility of posterization in subsequent editing. In any event, the histogram will always highlight any gaps in tonality.



Channel: RGB
Source: Entire Image

fig.13 (top) These histograms illustrate the effect of posterization. An 8-bit image file (a) was subjected to a number of rigorous tonal manipulations, which resulted in many unsightly discontinuities of tonal distribution (b), but in (c), where the origin was a 16-bit image file, this did not happen.

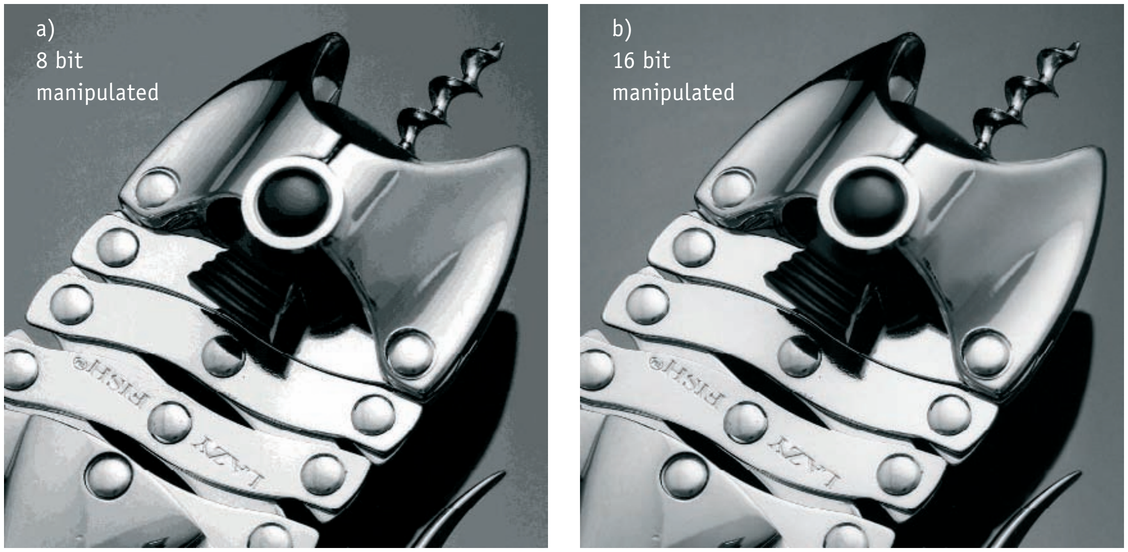


fig.14 (left) An identical sequence of tonal manipulations were applied to these images. The 8-bit image (a) shows clear signs of posterization. The 16-bit image (b) shows no signs of gradation and features smooth and realistic image tones.

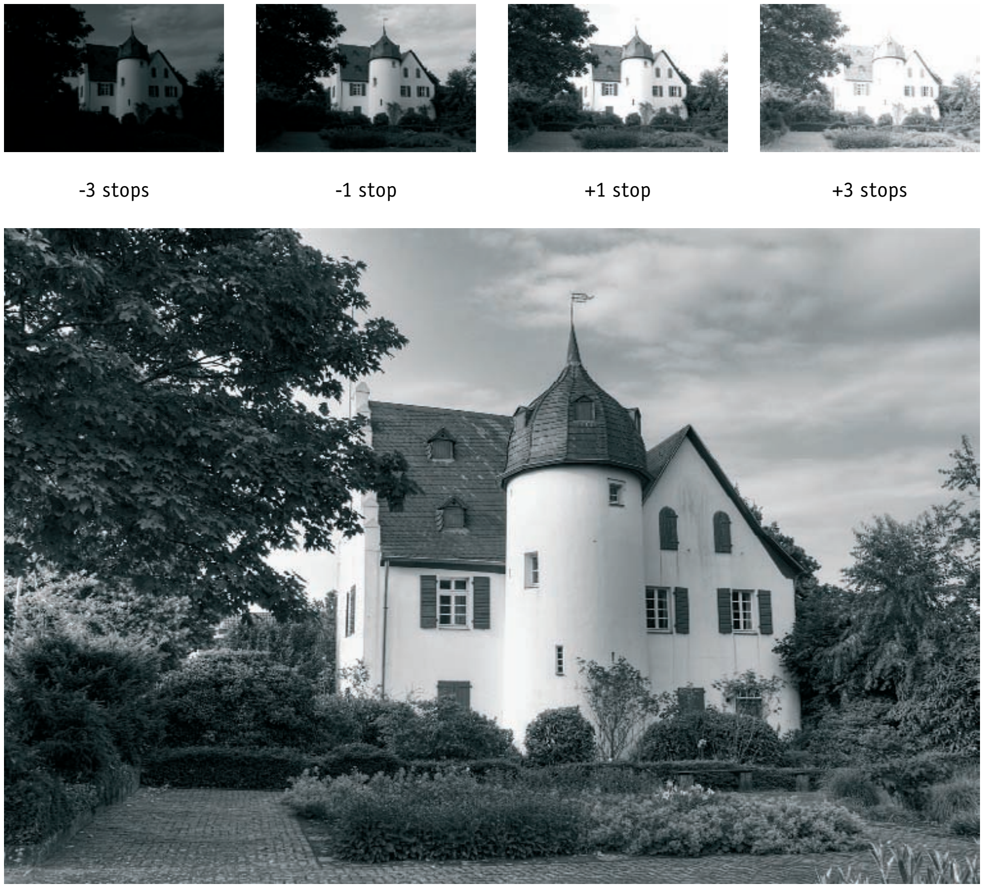


fig.15 High Dynamic Range imaging, or HDR, relies on blending two or more different exposures of the same scene. The exposures typically range from several stops of underexposure to several stops of overexposure. The dynamic range of an image can be extended beyond photorealism this way, reaching into surrealism.

## Dynamic Range

The average photographic scene has a subject brightness range (SBR) of about 7 stops. In extreme lighting conditions, this range can be as low as 5 or as high as 10 stops. The dynamic range of an optical recording device is the maximum brightness range within which it is capable of obtaining meaningful data.

The human eye has an amazing dynamic range. The retina provides a static sensitivity range of about 6 stops. With the support of a light-regulating iris and quick selective viewing, the sensitivity range is extended to about 10 stops. Adding the ability to chemically adapt to a wide range of brightness levels, our eyes have a dynamic range of almost 30 stops.

With film and camera, we do not have the flexibility of selective viewing, nor do we have the time for brightness adaptation during an exposure, but if processed accordingly, film has an exposure latitude of 15 stops or more. Digital cameras, on the other hand, are particularly challenged by large subject brightness ranges. The dynamic range of today's digital SLRs cannot compete with monochrome film and is typically limited to 7-9 stops. There are two solutions to improve matters considerably.

The first method is deceptively simple. A deliberate underexposure is made at a low ISO setting, so that the highlights are fully rendered and far from being clipped. This exposure is recorded at the highest bit depth possible and imported into the imaging software as a 16-bit file. Then, software image adjustments are made to lift the shadow detail and roll off the highlights, which effectively extends the dynamic range into the shadow region and lightens the midtones. Several extra stops of dynamic range can be gained this way. It is a technique used by wedding photographers to avoid overexposing the bride's dress while still capturing the weave in the groom's suit.

The second method relies on blending two or more different exposures of the same scene (fig.15). The exposures typically range from several stops of underexposure to several stops of overexposure. The dynamic range of an image can be extended beyond photorealism this way, reaching into surrealism. Sophisticated imaging software either supports combining the exposures manually, or it provides special features to automatically merge the exposures to one. This is called 'High Dynamic Range' or HDR. Creating a new image from two exposures, just a few stops apart, usually results in a realistic representation. More surrealistic images are made from several exposures covering an extreme subject brightness range. Every print has a finite contrast range, and simply squeezing in an unrealistic subject brightness range gives unrealistic looking results. This may serve to extend the boundaries of photographic creativity, but selective manipulation is the better choice if more convincing images are required.

## Preparing for Digital Output

The last steps of digital image manipulation are sizing, scaling and sharpening of the image to optimize it for a specific output device. Every image file has a set number of pixels that control the image resolution on screen and in the final output. If this resolution is changed, the image expands or shrinks in physical size, since the total number of pixels remains constant. The pixel resolution, required for on-screen display or printers, is usually quite different. As a consequence, the image file may have either an excessive or an insufficient pixel count for its final purpose. Typical computer monitors feature resolutions of 65-130 ppi, whereas inkjet printers and half-tone imagesetters may require anything from 240-450 ppi. To support specific output requirements, the image file must be re-sampled to the correct output dimensions and the appropriate pixel resolution.

Re-sampling an image may create additional, or eliminate existing, pixels through a process called interpolation. This process requires that new pixel values be calculated from neighboring pixels in the original file through a number of alternative algorithms. Reducing the pixel count discards information and reduces image resolution. Conversely, increasing the pixel count does not increase resolution or add detail. It is important to make sure that there is sufficient resolution to support the intended print size before committing the data file to digital output. See the text box, earlier in this chapter, for some popular print sizes and their recommended image resolutions.

## Sharpening

Due to all the mathematical acrobatics of generating new pixel values from neighboring pixels, and the use of optical anti-aliasing or moiré filters in front of the sensor, most digital images require some degree of sharpening. This is applied either within the camera software, right after image capture, or more controllably, at the last stages of image manipulation. The best practice is to sharpen the image just prior to reproduction. For that reason, professionals will keep a manipulated, but not sharpened, version of a premium image in addition to several reproduction copies. It is also a good practice to sharpen the image only where required. For instance, sharpening clouds and other areas of smooth tone has no pictorial benefit and may only accentuate image noise. This is another incentive to work exclusively with camera raw files and not to rely on in-camera sharpening for quality work.

Behind the scenes, the sharpening process involves re-calculating each pixel value again, based upon its relative brightness to neighboring pixels, always looking for opportunities to improve acutance. There are different sharpening tools available, all optimized for specific image styles, and each with its unique control settings. The most common and universal software tool is the so-called ‘unsharp mask’, which achieves mathematically the same optical effect as the darkroom process of the same name. Most applications provide a preview of the outcome (fig.16d), and one is well advised to evaluate the results, close to the final print scale, with the preview zoom level set to 100%, 50%, 25% and so on. Other zoom levels may create strange on-screen effects and disguise the sharpening effect. There are no ideal settings for the unsharp mask, since the optimum level changes with image resolution, size, noise and content. However, software sharpening is easily overdone, and less is often more.

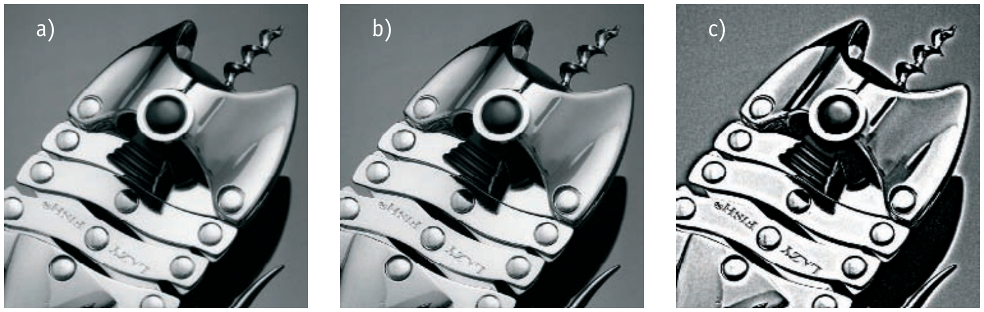
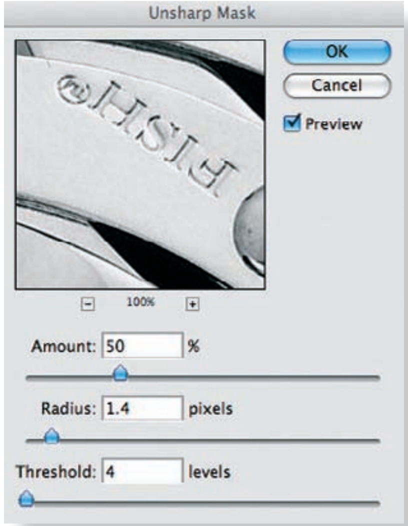


fig.16a-c Soft images (a) are carefully sharpened (b) to restore their original brilliance. However, software sharpening is easily taken too far (c).



☑ Preview

Amount: 50 %

Radius: 1.4 pixels

Threshold: 4 levels

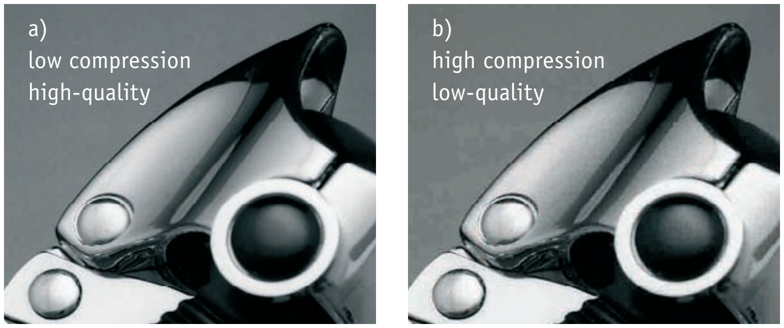
fig.16d The ‘Unsharp Mask’ dialog box in Photoshop offers three main controls, which affect the level of sharpening, the spread of the mask and a threshold to avoid accentuating image noise. The settings shown here are a good starting point and also avoid over-sharpened and unsightly images.

The examples in fig.16a-c compare different levels of sharpening. A slightly soft image (a) was sharpened with an unsharp mask, using the starting-point settings in fig.16d, which successfully improved image sharpness (b) and restored the original subject brilliance. A much stronger setting exaggerated image contrast (c), and delivered an unsightly print, similar to what we get from the office copy machine.

## Imaging File Formats

The image file is the digital equivalent of a traditional negative, and as such, it is considered to be the image original. As with film negatives, digital image files deserve the utmost care, otherwise, the original image is lost forever. The first consideration is usually the choice of format in which the image file should be stored. This initial choice of file format defines the limits of digital image compatibility and quality.

We differentiate between uncompressed and compressed file formats. File compression is used to reduce the file size of the digital image, and is either lossless



a) low compression high-quality

b) high compression low-quality

fig.17 Image files are stored in uncompressed or compressed formats. Some algorithms eliminate image information considered to be of minor significance, according to preset compression levels. However, once image information is lost, it cannot be brought back.

or ‘lossy’, in which case, image quality is likely to be compromised to some degree. Lossless compression schemes simply eliminate data redundancies, and it is very effective with images that contain large homogeneous areas or repetitive patterns. With other images, the data reduction is insignificant, and the file size may even inflate. Lossy compression algorithms eliminate image information considered to be of little interest to the viewer, and file sizes vary according to compression factor. However, once image information is lost, it cannot be brought back.

Several file formats dominate the consumer and professional markets. It is wise to preserve not only the manipulated version of an image, but the original camera image as well, so that one can take advantage of improved editing with the latest software.

**JPEG (.jpg)**

This image file format was created by the Joint Photographers Experts Group and is the most compatible, highly file-size efficient and well-established lossy compression scheme. JPEG files are often found as the default format in consumer digital cameras and as the ‘snapshot’ alternative in professional SLRs. JPEG files support RGB and CMYK color spaces, but are limited to 8 bits per channel. They are a compromise in quality, often leading to unsightly artifacts at high compression rates. They are not a good choice for extensive image manipulation or high-quality work.

**TIFF (.tif)**

The Tagged Image File Format, or TIFF, can be uncompressed or compressed but is always lossless and records 8, 16 or 32-bit grayscale, RGB or CMYK images. The format has developed into a stable standard, is widely compatible with desktop publishing software and popular with professional printers. It also records additional image layers, masks and paths. Some digital cameras can produce TIFF files directly.

**Photoshop (.psd)**

Photoshop files are included here, simply due to the dominance of Adobe Photoshop in the marketplace. Photoshop’s file format is well compressed and lossless, while allowing for a maximum degree of editing flexibility and compatibility with other formats, as long as you own Adobe Photoshop. The file format supports an assortment of color spaces, and just like TIFF, preserves image layers, masks and paths, at the expense of file size. This overcomes the limitations of Photoshop’s destructive editing nature. Photoshop is frequently updated, and its feature set is always improved and extended. However, version control is required to maintain backwards file compatibility.

**Camera Raw (.nef, .cr2, .orf, ...)**

File formats in this class record image data directly from the camera sensor with a minimum of in-camera processing. In-camera processing is a compromise to maximize speed and lower power consumption, and is best kept to a minimum. The format is used to store high-bit-depth RGB images, and allows the user to tune exposure, sharpness, contrast and color balance, to name just a few image characteristics. Camera raw files have the best potential to produce high-quality images. Unfortunately, each manufacturer has a proprietary camera raw format, which is upgraded with new camera releases. This often demands computer software updates and is exploited by some companies to force upgrade purchases. Early attempts to standardize raw formats have failed, and it is not certain that older formats will remain supported in new operating systems and applications. In view of this, our recommendation is to always start with a camera raw file, but archive original image files as either ‘Digital Negatives’ or as high-quality, 16-bit TIFF files, which are, unfortunately, very demanding of space.

**Digital Negatives (.dng)**

This image file standard is an open format, created by Adobe, in an attempt to overcome the transitory nature of camera raw files. It is meant to be an archival format, containing the essential image data of proprietary camera raw files. It is lossless but highly compressed, and by creating this industry standard, it is hoped that obsolescence will be reduced. Major consumer brands will be the last to desert their proprietary formats, especially while improvements and software enhancements are still numerous. In view of this, it is comforting to have an open image format, which promises to support longer-term archiving.

## Archival Storage

In order to store digital image files safely for a long time, it is worth considering a few obstacles. In addition to its limited life expectancy, restricted through physical and chemical deterioration, digital media also faces the problem of obsolescence. Media obsolescence is most frustrating. Nothing seems to be immune from the march of technology. One may have stored images on reliable recording media under the best environmental conditions, only to find out that hardware interfaces, software applications, operating systems or recording media have changed yet again, and that there is no easy way to get to the image data anymore. The new software version cannot read the old files, the old hardware interface is incompatible with the new computer or the new hardware does not accept the old storage media. One's only defense against both deterioration and obsolescence is to transfer digital image files occasionally from old to new storage media with or without an upgrade in technology.

However, the life expectancy of electronic media and its time to obsolescence vary greatly. Removable media in the form of optical disks, as in CDs and DVDs for example, are prone to physical and environmental damage. As with print storage, temperature, humidity, exposure to light, handling and airborne oxidants all contribute to early failure. In addition, the material choices, laser power, write-speed and the manufacturing variations between disks affect the longevity of the media as well.

There are three main categories of optical disks: read-only, recordable and rewritable. They all have a polycarbonate plastic substrate but differ in data-layer technology. Read-only CD/DVD-ROM disks are by far the most reliable, because the data is molded into the disk as a spiral track of pits, similar to the grooves in audio records, and a laser reads the digital information from the pits. Unfortunately, their manufacture requires industrial-size machinery, which prohibits their use for individual image files. Recordable CD/DVD±R disks use a gold or silver layer, coated with an organic dye, to store the data. As the laser records the information, the dye becomes discolored, which encodes the information. The gold variety of disk is very durable, and their low-light life expectancy is assumed to be 20 years or longer. Rewritable CD/DVD±RW and RAM disks, on the other hand, use a metal-alloy film on aluminum, which is subject to premature oxidation and, therefore, not recommended for long-term storage.

It must be mentioned that the organic dyes used in recordable media are very sensitive to UV radiation and will deteriorate within days or weeks in strong sunlight. The Optical Storage Technology Association (OSTA) state that it is extremely difficult to estimate expected disk life, but suggest that the shelf life of unrecorded media may only be from 5-10 years. It also casts doubt on some manufacturers' claims of optical disks lasting up to 50 years. There is an ISO standard for accelerated testing, but it only considers temperature and humidity variation. Poor technique, manufacturing variability, recorder settings, handling

**Use for Digital Image Storage**

| | |
|---|---|
| CD/DVD-ROM | long-term |
| CD/DVD±R | medium-term |
| CD/DVD±RW | short-term |
| CD/DVD-RAM | short-term |

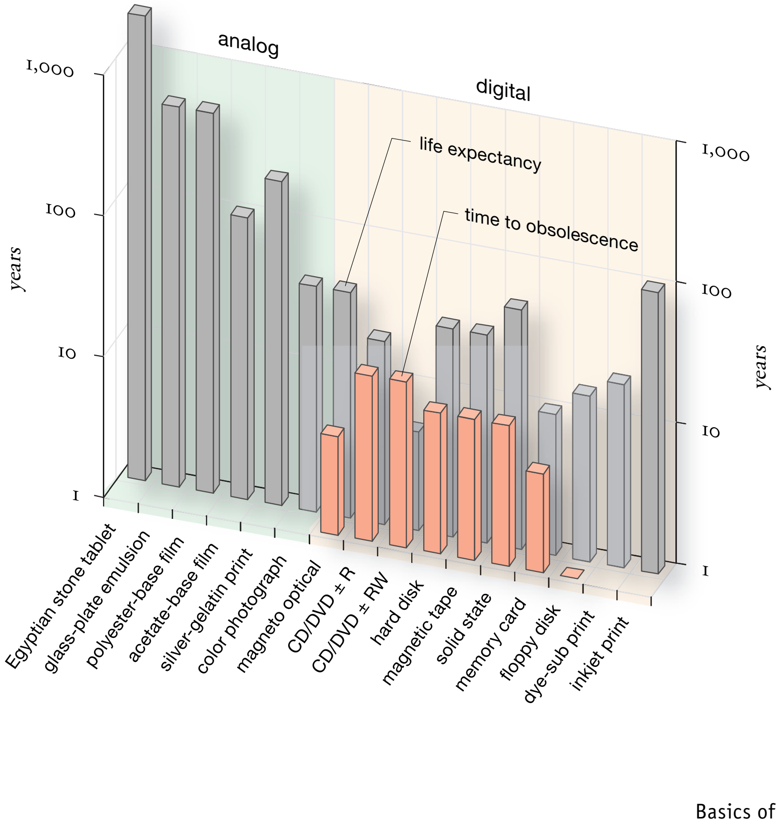


fig.18 In addition to its limited life expectancy, digital media also faces the problem of obsolescence.

and storage method will significantly reduce data life expectancy. Several institutions have reported their disks failed within 2 years, for no obvious reason. Some, consequently, have switched to magnetic storage methods, such as hard disks, magneto optical disks or tape systems for long-term backups. Indeed, an external hard disk, used for backups, may be an ideal long-term solution, but many users prefer to use optical media for convenience and economy.

Best practice mandates high-quality materials, optimum recording media and image data storage under ideal conditions. First, make sure that your hardware and software is up-to-date, which ensures that it matches the capabilities of the latest media. Second, choose gold CD/DVD±R disks, advertised as archival, handle them at the edges only, and record at slow data rates. Verify the disk after recording, and store it vertically in an inert, acid-free sleeve, in a cool, dry and dark place. Use a common file format and avoid the proprietary formats found with back-up programs to avoid future compatibility issues. (For example, the Windows 2000 operating system cannot read the Windows 98 backup file format and, worse, modern PCs cannot load Windows 98 or Windows 2000, because they do not have the necessary hardware drivers).

It is essential to name digital files descriptively and catalogue archives, because it is all too easy to lose an image in the metaphorical haystack, without being able to search, find and see its metadata. Several commercial software programs are available to logically store, effectively search and quickly retrieve digital image files. Finally, each time you update equipment or software, it is advisable to check the compatibility of your archives with the new hardware and software before disposing of the old equipment.

Against this backdrop of uncertainty, it is worth remembering that, as long as there are optical systems, monochrome film negatives have no real media obsolescence. They can be projected, copied, scanned and simply investigated with a loupe. Their chemical and environmental deterioration is well understood and relatively easy to control within known limits. Film and paper have a proven track record of over 150 years in real-world conditions, and have no need for questionable advertising claims, which are at best derived from accelerated testing. We like to think that the best of our creative efforts will last. While negatives are sitting patiently, unattended and just waiting to be discovered, digital image files might last for a long time, but their dormant bits and bytes are likely to be unreadable by future generations without constant checking and re-recording. Who knows, the best way to preserve digital images may be to convert them to analog files! A currently popular option is to print them with archival inks on archival paper and keep them in a cool, dry and dark place before they irretrievably fall into what some image conservationists refer to as the 'digital gap'.

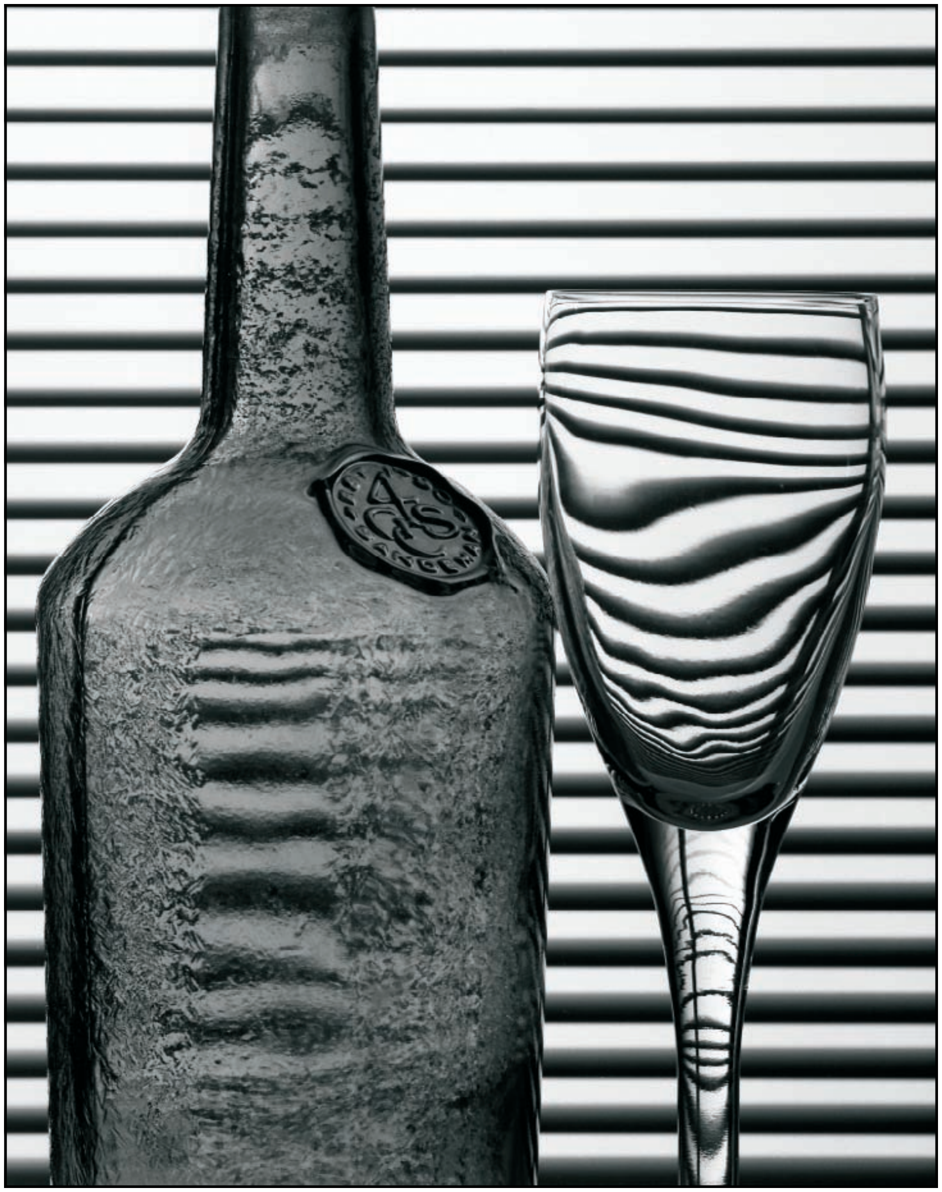
**Handling and Storage Recommendations for Digital Optical Media (CD/DVD disks)**

1. Handle disks by the outer edge or the center hole. Don't bend them, and don't touch the surface.
2. Use only a non-solvent-based felt-tip marker, not a pen or pencil, to write on the label side of the disk. Don't use any adhesive labels.
3. Keep disks clean, and remove stubborn dirt with soap and water, or isopropyl alcohol.
4. Don't expose disks to prolonged sunlight and avoid extreme temperatures or humidity levels.
5. Store disks upright, and return them to acid-free storage containers immediately after use.
6. Keep disks in a cool, dry and dark environment, free of airborne pollutants.
7. A temperature of 18°C and a relative humidity (RH) of 40% is considered practical and suitable for medium-term storage. A lower temperature and RH is recommended for long-term storage.

# Digital Capture Alternatives

## Comparing and choosing solutions for digital monochrome

The roots of this book are planted firmly in the traditional domain. Despite the allure and advances made by digital cameras and printers over the last decade, nothing approaches the beauty, permanence and depth of a toned, fiber-base print. Given that an image may not have been initially intended as a traditional monochrome print, or requires manipulations that are most efficiently performed digitally, this chapter compares the alternative methods necessary to bring an image, either directly or indirectly, into the digital domain for the purpose of editing and final output onto silver-based photographic paper. Clearly any recommendation will be challenged by evolving technology, and so, the assessment criteria and methods are explained, to be reevaluated in the user's own time.



### Imaging Paths

The diversity of available media, printing methods and imaging equipment make the many and varied routes from subject to final image worth contemplating. Disregarding web images for the moment, fig.1 shows an overview of the possible imaging paths from subject to print. Of interest, here, are the highlighted items, which bring an image into the digital domain for editing and still allow a full range of output options into analog printing. When deciding on the capture method, apart from the immediate issues of recording the subject satisfactorily, it is also necessary to consider the demands of downstream requirements, which are related to print size, printing method, archival requirements or accepted media.

Clearly, there are two main starting points for imaging a digital file: a) indirectly through film-based systems or b) directly from a digital camera. Our comparisons between analog and digital systems are made without reference to specific models. We have instead referred performance to quoted specifications,

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50021-1

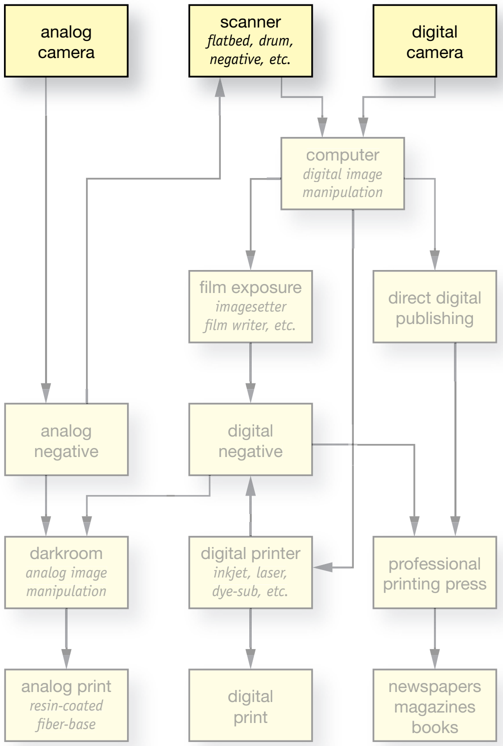

analog camera
scanner
flatbed, drum, negative, etc.
digital camera
computer
digital image manipulation
film exposure
imagesetter film writer, etc.
direct digital publishing
analog negative
digital negative
darkroom
analog image manipulation
digital printer
inkjet, laser, dye-sub, etc.
professional printing press
analog print
resin-coated fiber-base
digital print
newspapers magazines books

fig.1 There are many ways to get from image capture to the final print. In this chapter, we compare several digital capture alternatives to film, in order to explore the limitations of producing a high-quality, silver-gelatin print from digital capture.

which allows the reader, up to a point, to infer the performance of future digital equipment. Clearly, any conclusion is wholly dependent upon the relative importance of an image's quality parameters, and, without some conscious prioritization, can be the subject of endless debate. It is not uncommon for protagonists to infer superiority of one path over another, based on a single parameter and conveniently ignore others. Their relative importance also changes with consumer trends. Especially, quality and longevity are disregarded over the marketed appeal of new technology. The relative importance of these parameters also varies with the intended imaging purpose. For instance, a significant advantage of a digital camera is its ability to adapt to the ambient light color temperature, but this is, of course, of little value for monochrome work.

In these assessments, we assume that the underlying purpose is always to make a monochrome print on silver-based photographic paper with qualities suitable for a fine-art landscape photography. We cover aspects that are directly measurable, as well as our subjective evaluations. Each of our readers should consider their own priorities and shuffle the following parameters in order of importance and according to taste, image style and application. Beyond these considerations is the truism that any camera or photo is better than no camera or a missed shot.

## Quality Parameters

### Dynamic Range

The chosen capture system should be able to record the required subject brightness range and ensure a full-range print can be made with sufficient highlight and shadow detail. Digital and film media have an inherent capability, both of which can be enhanced, to some extent, by software and darkroom controls, respectively. The dynamic range of an optical recording device is the maximum brightness range within which it is capable of obtaining meaningful data.

### Resolution

Another significant consideration is the effective system resolution. In the chapter 'Sharpness and Depth of Field', we define the closest comfortable viewing distance for a print at about 250 mm and the standard viewing distance as approximately equal to a print's diagonal dimension. Human vision can, in general, resolve about 7 lp/mm on a print at 250 mm. As the viewing distance increases, print resolution can be lowered without obvious detection, although humans can distinguish prints with higher resolution beyond their physiological limit. The imaging system should meet or exceed the performance threshold of standard human vision. The requirements for film or digital media vary with format. Fig.2 lists resolution requirements and sampling rates needed to effectively capture them at two MTF contrasts, 10 and 50%, which imply the limit of resolution and acceptable sharpness.

### Tonality

Once any image, irrespective of the source, is in the digital domain, the subjective distribution of tones between highlights and shadows is under the direct control of the imaging software. Extreme tonal manipulations require images with low noise and a high bit-depth, as camera raw files and 16-bit film scans. For monochrome work derived from digital color originals, there is an interesting twist, because when the starting point is a color original, one can change the monochrome tonality by employing filtration, just as one does on-camera with monochrome film.

### Sharpness, Grain and Noise

These attributes are intentionally grouped together, since a significant improvement in one often causes obvious deterioration in another. Images obtained by scanners or digital cameras are best captured with minimal sharpening settings and then sharpened to the required level in the imaging software. Sharpening algorithms amplify image grain and noise, and can also dramatically change image appearance. Conversely, image noise or grain can be reduced with digital blurring filters, at the expense of image sharpness and resolution. More advanced digital filters and plug-ins exist, and they are constantly evolving to intelligently minimize image degradation. However, one ought to fully understand the existing software filters before reaching for costly alternatives.

A note of caution: the initial visual appeal and ease with which a digital image may be sharpened often leads to its over-application. While image sharpness may hold sway over image resolution, its over-use destroys tonal subtlety and resolution. It is important to be aware of the balance and interaction of the sharpness controls with unwanted image side effects for each proposed system and make one's own assessment of the optimum balance. Although most individuals can effectively compare side-by-side image sharpness, a proposal is made later on for an absolute measure.

Pause a moment to qualify the above mentioned quality parameters and consider your own print-making experiences. For instance, although fine images often require high levels of resolution, it may be possible to work with less, based upon image content and viewing conditions, especially if the image has simple shapes, is noise-free and sharp. It would be imprudent to say that you cannot have a fine print without these qualities, but if you choose the optimum solution, you are less likely to be caught out by the chosen subject matter or final image application. Many excellent images have been and will be made with less than ideal equipment and materials. Whether or not they are considered as fine art is another question, which only time will answer.

## Measuring Digital Resolution

A direct comparison between digital and analog sources is not easy, since digital cameras, scanners and film systems use different performance measures to evaluate their resolution. It requires some analysis to establish a reliable correlation between the measurement systems, since we use lp/mm to measure film resolution, samples per inch (spi) to measure scanner resolution and sometimes other measures for digital cameras. Scanner specifications themselves can be misleading in two respects. Firstly, by using 'dpi' rather than 'spi', because dpi, or dots per inch, refers to the resolution of the printed file, whereas spi, or samples per inch, refers to the resolution of the scanning system. Secondly, the equipment spi rating is calculated from the sensor pitch and tracking increment, and takes no account of the effective image resolution of the optical system, which is often found to be lacking. Many scanners are not able to retrieve the full potential of a negative, and one must always evaluate the combined performance of the film system and scanner.

| image format | resolution requirement | | |
|---|---|---|---|
| | | MTF | |
| | | 10% | 50% |
| | [lp/mm] | [spi] | [spi] |
| 16x24<br>(DX format) | 67 | 3,600 | 4,500 |
| 24x36<br>(FX format) | 45 | 2,400 | 3,000 |
| 6x4.5 | 26 | 1,400 | 1,700 |
| 6x6 | 24 | 1,300 | 1,600 |
| 6x7 | 21 | 1,100 | 1,400 |
| 6x9 | 19 | 1,000 | 1,300 |
| 4x5 | 11 | 600 | 750 |
| 5x7 | 9 | 470 | 600 |
| 8x10 | 6 | 300 | 380 |
| 11x14 | 4 | 210 | 270 |

fig.2 Different scanner sampling rates are needed to satisfy the resolution limits of standard vision (10%) and that required to resolve the same detail with acceptable sharpness (50%). The spi figures shown assure a contrast of 10% and 50% at the required lp/mm.

One should first consider how digital sensors resolve an image, both theoretically and practically, before setting out to measure their performance. We know that typical digital sensors are made of a regular array of photosensitive elements, and one may wrongly assume that only two lines of sensors are required to resolve a resolution test chart line-pair image, suggesting that 51 spi can distinguish 1 lp/mm. This is a special case, referred to as the Nyquist frequency or cutoff. Although apparently correct, any misalignment between the sensor and the incident image reduces the detected line-pair contrast and, in some conditions, lines are not detected at all. Fig.3 shows how this might happen with the familiar 3-bar pattern of a USAF/1951 chart, imaged onto the array of a typical digital camera sensor. In the first case, where there is almost perfect alignment (fig.3a), the test pattern is fully resolved, but if the image is shifted slightly (fig.3b), no or all pixels are recorded, as all sensor elements see the same image intensity.

With a few calculations, the MTF values for different sensor pitches and alignments can be easily approximated. Reducing the sensor pitch to 2.1 pixels per line pair guarantees line resolution with a minimum of 10% contrast between the lines, and reducing the sensor pitch to 2.6 pixels per line pair guarantees the same with a minimum of 50% contrast. In other words, in order to resolve 1 lp/mm, we need 25.4 x 2.1 or 53 spi for 10% and 67 spi for 50% MTF.

Unfortunately, we can't just divide the orthogonal pixel count of a sensor by 2.1 to calculate the actual resolution limit of a digital system. An imaging system's overall MTF is the product of the individual component MTF performances. For instance, the camera lens, film or sensor, digital negative process, enlarging lens and paper all affect the final outcome. However, it would make it difficult and rather confusing if we accounted for all influences of all contributors in the optical system. It is better to understand the impact of each component individually. Consequently, for the rest of the book, we stick to the theoretical values and assume a sampling rate of 53 spi per 1 lp/mm to calculate the resolution limit at 10% MTF, and work with 67 spi per lp/mm to obtain resolution at acceptable sharpness and 50% MTF.

When one rotates either the target or the sensor, the effective sensor pitch decreases, increasing resolution in that orientation. When the grid or sensor is rotated

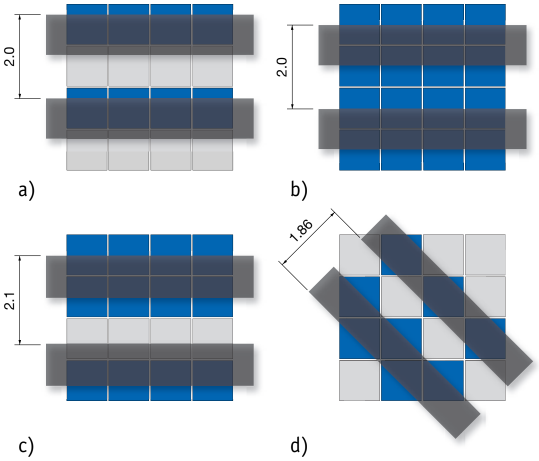


fig.3 Maximum digital resolution changes with alignment and rotation between image sensor and subject detail.

a) *best-case scenario*
Sensor matrix and test pattern have the same pitch (2 pixels per line pair) and are in almost perfect alignment, which leads to a fully resolved pattern.

b) *worst-case scenario*
Sensor and test pattern have the same pitch, but the test pattern is moved down by 1/2 pixel. Pixel detection is ambiguous and no pattern is resolved.

c) *improved worst-case scenario*
Same as top right, but the test pattern pitch is increased to 2.1 pixel/lp. This lowers the actual sensor resolution, but the test pattern is now clearly resolved.

d) *maximum rotation*
The test pattern is rotated by 45°. This allows the pattern pitch to be reduced to 1.86 pixel/lp. The test pattern is still fully resolved, and the sensor resolution is at its maximum.

45°, the effective pitch between diagonal rows of pixels is reduced to 1.86 pixel/lp (fig.3) giving a small resolution improvement of about 13% above the theoretical value. This means that any sensor array, or scanner image, has a range of performance values, depending on the angle of the image. In practice, fine detail like fabric, hair, and grass are oriented at many angles. We assume the worst case orthogonal requirement, since other orientations of this admittedly theoretical image onto a sensor array can produce distracting results, as the image slips between adjacent sensor elements along its length. We shall compare digital camera and scanner resolutions with both orthogonal and diagonal images and use the 53 spi per lp/mm conversion factor to directly compare orthogonal resolution measures, at 10% MTF.

### MTF as the Standard for Resolution and Sharpness

For this evaluation, we shall use a derivation of the standard Modulation Transfer Function (MTF), described in ‘Sharpness and Depth of Field’. We avoid the traditional fixed test pattern, in three scales and two orientations, in favor of a variable-scale MTF target. This is similar to the Sayce chart, described by Norman Koren (www.normankoren.com), and uses a decreasing pattern scale (increasing lp/mm). The test target is shown in fig.4. The test method requires the test target to be photographed with the camera system set up at a known image magnification. The direct or indirect digital capture method follows and the image is evaluated with imaging software and on a life-size print. We define the system resolution limit as the point where the image contrast reduces to 10% of the maximum contrast possible. The continuous scale in fig.4 is also preferred since it highlights imaging aliasing issues and avoids ‘lucky’ measurements, where perfect alignment of sensor and image occur. At this resolution, the target image becomes a series of faint light and dark mid-gray lines. The limit of acceptable sharpness for the element or system may be implied from the lp/mm value at which the image or print contrast is reduced to 50%. The contrast measurement is accomplished by evaluating the image file or scan and reading the brightness differences between lines with the eyedropper tool of the imaging software.

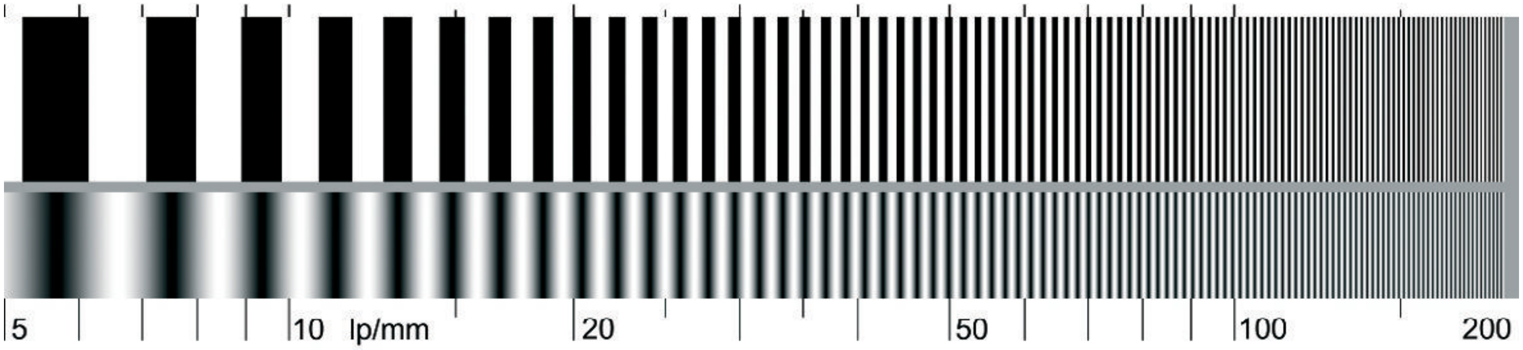


fig.4 When printed 200mm wide, the scale is exactly 100x larger than life and assumes an image magnification of 1/100. If the image magnification of the test setup is only 1/20, the scale reading should be divided by 5. A copy of this template can be found at www.normankoren.com.

It should be noted that it can be misleading to compare different capture systems' sharpness, which deploy automatic processing, since sharpness can be radically altered by sharpening algorithms in the imaging software. For instance, it is not uncommon to record a contrast figure exceeding 100% in digital imaging systems, (see fig.8). This is an indicator of over-sharpening of the digital image file, as is a sharp rise in contrast before a dramatic reduction into chaotic oblivion, similar in shape to the filter response in electronics, named after the scientist Chebychev.

## Comparing Image Capture Alternatives

The following assessments compare the performance of typical digital SLRs with 35mm roll film and larger film formats, using a range of scanning solutions. The scanning solutions include dedicated film scanners, hybrid flatbed/film scanners and a novel scanning method, which uses a flatbed scanner and a conventional RC print. While the results may change over time, the test methods need not and are described so that one might assess their own equipment and evaluate the latest digital equipment. It is worthy to note that many scanners cannot retrieve the full potential of most lens/film systems, and any increase in available scanner performance will immediately improve your entire image collection, whereas an original digital raw file is as good as it gets.

### Dynamic Range

Current digital cameras are not able to record the wide subject brightness range (SBR) that we are accustomed to with monochrome film. Their dynamic range is fundamentally determined by the noise levels of the imaging sensor and its bit-depth. This is easily confirmed by photographing a transmission step tablet placed on a light box. However, the unadjusted dynamic range is already better than slide film, at about 8 stops. Some models claim 9 or 10 stops, but the extra range is not symmetrically distributed about Zone V. In comparison, with appropriate development, a monochrome film can easily record a SBR reaching 15 stops. Typical tonal responses, for slide film, raw digital data, and software-adjusted image data are shown in fig.5. A pictorial comparison, without manipulation, is shown in fig.6a and fig.6b. The dynamic range is established by noting the exposures which produce the digital values of 4 and 96% K, or when printed, reproduce the traditional, absolute reflection densities of 0.09 and 1.89 on the paper.

An analog-to-digital comparison of dynamic range should also consider tonal quality. A digital sensor response is characterized by exaggerated highlight contrast and a long extended shadow toe. To mimic a typical film response, the digital camera exposure must be set so that it does not miss any highlight information (clipped highlights), and it should be recorded in a high-bit file format. The full histogram is then manipulated in the imaging software to reduce the local contrast of highlight regions and boost that of the shadow and midtones (fig.5).

Although extra shadow detail can be recovered by extensive tone-curve manipulation, this action will also accentuate sensor noise, or worse still, if the image is in an 8-bit mode, may cause image tone break-up and posterization in areas of smooth tone. This is a rescue technique, which accentuates sensor noise and does little to tame the highlight appearance. This issue will be overcome as sensors improve their signal to noise ratio (SNR) and their dynamic range is expanded with improvements in analog to digital converter (ADC) resolution.

Throughout this book, the importance of ensuring sufficient negative shadow detail has been emphasized. Conversely, with positive film or digital camera files, the opposite is true, and overexposure is to be avoided at all costs, since it is all too easy to

fig.5 This graph compares the tonal response of slide film with unadjusted digital raw data and software adjusted image data. Notice the difference in tonality between the exposure extremes, and see how the slide film quickly rolls off at the exposure extremes while accentuating midtone contrast. Negative film (not shown), normally developed, easily captures the full 10-stop range of this test target.

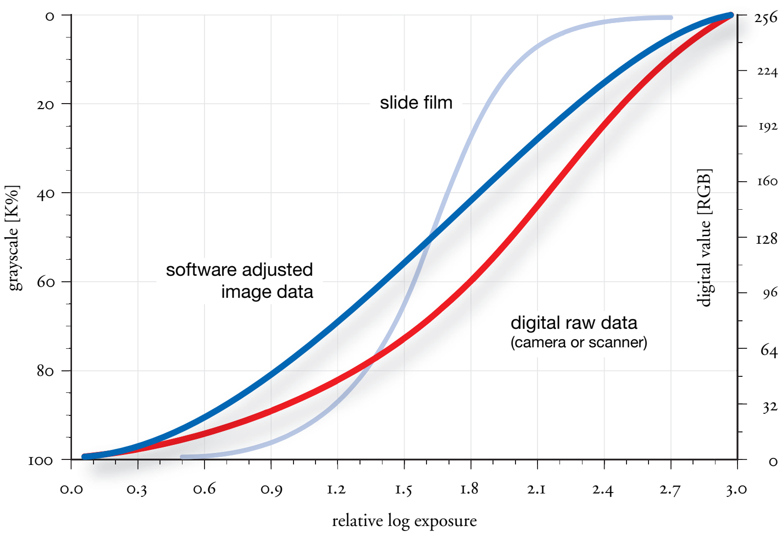
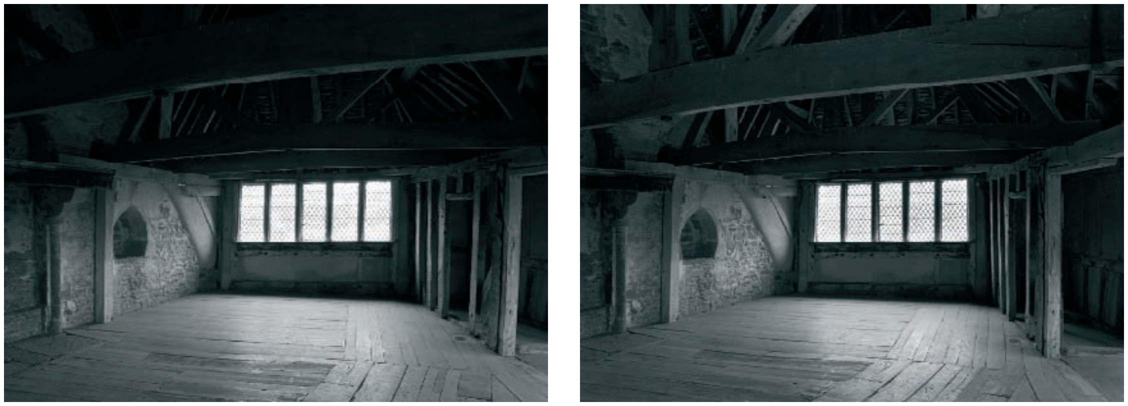


fig.6 (a) This image is a straight print from a digital SLR, using its raw file setting. Although there is shadow detail, it is tonally compressed and at the same time, the windows are burnt out. To mimic the traditional print, the image would have to be deliberately underexposed and then a correction curve applied to the mid and shadow tones to lift the detail. This accentuates sensor noise. (b) The same scene in a straight print from an Ilford Delta 100 negative, given normal development. There is plenty of detail in the shadows, and on the print, faint tracery is seen in the windows, which can be emphasized by burning-in. Both images were made at an identical ISO and camera exposure setting.



a) digital camera

b) analog print

exceed the exposure cut-off point and irretrievably lose highlights. Although some cameras deploy two sensors in each position to improve the highlight response, even these do not appreciably extend the dynamic range. In some cases, slide-film techniques, such as using a graduated neutral density filter to lower a sky's intensity may avoid subsequent rescue techniques. For static subjects with a large SBR, another technique, called High Dynamic Range, or HDR, using two or more different combined exposures can, with care, capture a full range of subject tones. This technique requires a stationary subject, a tripod and subsequent manipulation. In comparison, the combination of monochrome film and a film scanner effortlessly capture sufficient dynamic range in the most demanding of situations.

**Resolution**

After extensive testing and considering our resolution requirements, fig.7 tabulates the required and measured lp/mm and peak imaging capabilities for several sensor and film formats. Fig.9 shows this in graphical form, along with the typical film resolutions after scanning, in relation to the diffraction limit and resolution requirements for several formats. These resolutions were obtained using our MTF test target at the point where the digital image contrast dropped to 10%. These results are discussed later in more detail for each of the different capture solutions.

Images taken with current digital cameras (FX or DX format) have about 1/2 of the effective print resolution of fine-grain, 35mm monochrome film, taken with quality equipment. Their limited pixel count limits their performance. Even as pixel count increases, one should note the required resolution demands placed upon SLR optics from the small DX format are difficult to achieve in practice and, before long, the lens, sensor SNR performance and size will limit the ultimate performance. Assuming an otherwise perfect optical and mechanical system, the maximum print size from a digital camera is calculated by dividing the pixel dimensions by the print ppi setting. An 8x10-inch print, at its standard viewing distance, requires 5.3 lp/mm print resolution, obtained by a 280 ppi file setting (5.3*25.4*2.1 = 280). A 10-megapixel camera meets this requirement, based on the assumption that the image is not cropped and the lens performance comfortably exceeds the sensor resolution. Theory suggests that this sensor should resolve 78 lp/mm orthogonally at 10% MTF contrast but, in practice, it achieves a sensor resolution of only 68 lp/mm, a 12% deterioration. A print crop, changing the print shape from 2:3 to 4:5, further reduces the resolution and takes it below the threshold for a fine print.

As the megapixel race continues, remember that doubling the pixel count only increases resolution by 41%. So, in the case above, it is predictable that a 20-megapixel camera will resolve a minimum of 7.5 lp/mm on a full 8x10-inch print, roughly half that required for critical observation. 35mm film is able to provide up to 11 lp/mm at this enlargement.

**Sharpness and Grain**

All digital images require some degree of sharpening, either in the capture hardware or in the imaging software, and often, the sharpening occurs behind the

| image format | resolution [lp/mm] requirement standard | critical | measured typical |
|---|---|---|---|
| 16x24 (DX format) | 67 | 201 | 68-76 (10-Mpixel SLR) |
| 24x36 (FX format) | 45 | 134 | 50-56 (12-Mpixel SLR) |
| | | | 63-71 (24-Mpixel SLR) |
| 24x36 | 45 | 134 | 95 |
| 6x6 | 24 | 72 | 75 |
| 4x5 | 11 | 34 | 65 |

fig.7 This table compares the on-sensor or on-film resolution requirements with the typically measured system performance for a range of formats necessary to deliver sufficient resolution in the final image and satisfy standard and critical observation.

scenes. In our comparisons, the images have been optimally sharpened to maximize resolution. In relation to their resolution performance, digital images have sharper images than darkroom prints from negatives. Using the 50% MTF contrast as a guide, the measured results in fig.8 show a gentle softening of contrast for unsharpened digital images and a more abrupt fall-off for sharpened images. Digital images from scanned film can be sharpened too but to a slightly lesser extent than one from a digital SLR. The higher image noise of the scanned image is emphasized by the unsharp mask and drops the optimal sharpening setting to a lower level.

One advantage of digital SLRs is their ability to take pictures at different ISO settings. At similar speed settings, digital SLRs produce smoother images than their 35mm film counterparts, and professional models can challenge medium-format roll film. At the highest ISO settings, however, the smooth imagery that characterizes digital images yields to objectionable noise, which is far less appealing than simple monochromatic high-speed film grain. High ISO settings are best avoided for fine art work, as the noise appearance is intolerable, the dynamic range is reduced and resolution is degraded.

## Scanner Assessments

### Film Scanner

Darkroom prints repeatedly demonstrate that monochrome film has the potential for sufficient resolution and dynamic range to make fine prints. To capture a negative for the digital domain, one needs some method of digitizing the film. Those models targeted at transparency scanning are advertised on their maximum film density and resolution. Luckily, negative film, in all but extreme circumstances, has a maximum transmission density of 2.0 and is well within the capabilities of all scanners. In this case, the film and development choices are the only limitations for the captured dynamic range. Most dedicated film scanners are able to capture sufficient resolution for a standard-quality print output, even from small format negatives. For example, a high-quality 35mm film scanner will resolve up to 62 lp/mm or 3,300 spi orthogonally, well above half its theoretical 4,800 spi specification. This scanning performance meets the resolution requirement for a full-frame 35mm negative, providing the negative itself has the required resolution, but film grain is obvious at this resolution and degree of enlargement.

Large and medium-format scanners were initially designed and priced for professional and commercial work, which has since moved over to a full digital workflow. The best medium-format scanners, we have tried, were limited to 56 lp/mm. This is fully sufficient for medium-format but borderline for 35mm negative scanning. A typical large-format scanners will resolve up to 32 lp/mm and, consequently, capture everything a large-format negative has to offer. As more users swapped film for digital cameras, the need and requirements for scanners changed, and excellent models have become harder to obtain.

A high-resolution film scanner will detect and sometimes emphasize film grain. Careful adjustment of the scanning parameters can prevent grain becoming obtrusive, normally accompanied by a small loss in image sharpness. Another consideration is their speed and convenience. While it is convenient to have 24/7 access to a film scanner, the time required to properly scan a negative should not be underestimated. It takes about 20 minutes to clean, preview, adjust, focus and scan a negative properly at a high resolution. This becomes tedious when multiple images require capture. Medium-format and large-format scanners are still specialist items and will remain expensive, to the extent that many photographers consider hybrid flatbed scanners an attractive alternative.

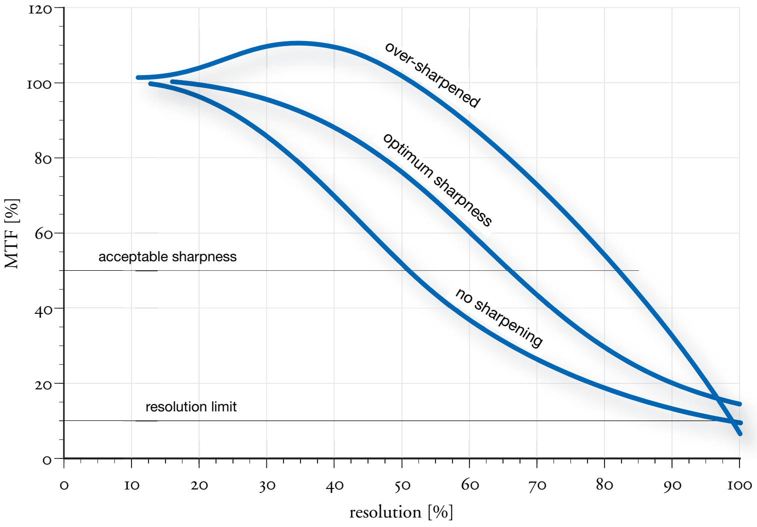


fig.8 This chart compares the contrast roll-off for a digital SLR image, at three sharpening levels. The resolution is normalized for the unsharpened digital image. The over-sharpened image shows significantly better sharpness at 50% contrast but ultimately resolves less fine detail, whereas optimum sharpening increases sharpness and resolution from that of the unsharpened image file.

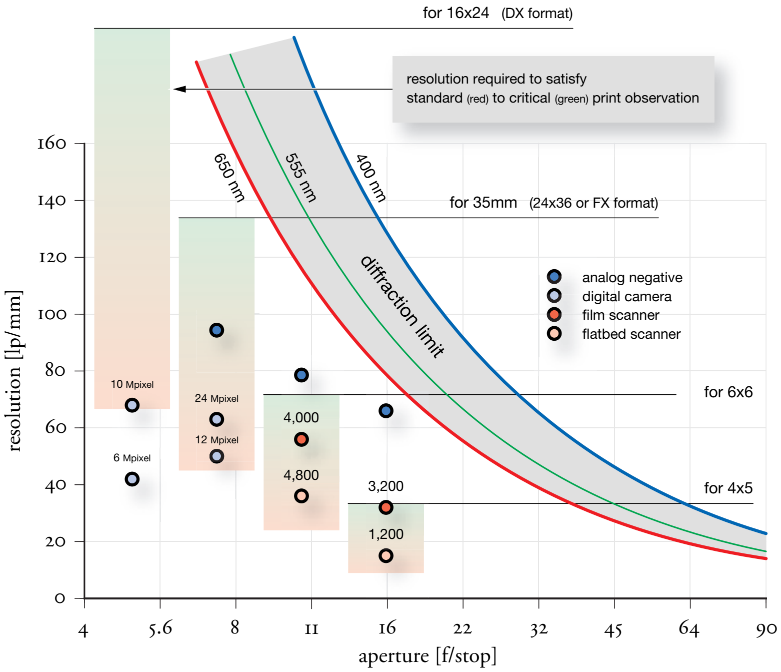


fig.9 Comparing the actual performance of several camera and scanner systems clearly illustrates the predictable quality differences. It clearly shows the barely acceptable performance of the DX format and the increasing performance headroom with increasing format size.

## Hybrid Flatbed Film Scanner

Every scanner manufacturer now has a hybrid version with a transparency scanning capability. In the beginning, scanning specifications were poor, at around 300 spi, but have improved dramatically, although the specifications of recent models, exceeding those of dedicated film scanners, are not met in practice. There are two main types: those in which the film is placed into a holder and slid into the body of the scanner, and those that scan the film placed on or close to the glass top, using a second light source in the scanner lid. Theory proposes the former solution to be optimum, since there is no glass plate to distort the optical path and, more importantly, no additional dust attracting surfaces to mar the result. The latter, however, is more popular for cost reasons. The better models hold the film away from the glass surface in special film holders, which prevent the appearance of Newton's rings in the scanned file and additionally ensure that any dust on the glass is not in the plane of focus.

In practice, the actual performance of flatbed scanners falls short of their quoted specification: For instance, a 'professional' flatbed film scanner with a declared resolution of 1,200 x 2,400 spi resolved only 15 lp/mm (800 spi), whereas a later model, claiming to capture 4,800 spi, actually resolved 36 lp/mm (1,900 spi). Both of these scanners fall short of the resolution requirement for detailed images from 35mm, but they provide sufficient resolution for scanning medium or large-format negatives. Hybrid scanners do, however, offer speed advantages over film scanners as a result of less data transfer, shorter lamp warm-up times and the use of a fixed-focus CCD position. It is clear that their optical performance is not as good as their actual CCD resolution, partly due to the fixed-focus design and poor manufacturing tolerances. On consumer hybrid scanners, the optimum plane of focus is frequently not at the position required by the film holder thickness and cannot be adjusted. In these cases, it is worthwhile to experiment with different focus positions by altering the film height with a modified or substitute film holder.

## Flatbed Print Scanner

There is a quirky fourth alternative that will produce excellent monochrome scans. This low-budget technique successfully challenges many film scanning solutions at a fraction of the cost, and delivers a significantly higher resolution, by performing the digital capture in two steps. The first step is to make a low contrast enlargement of the image area onto a sheet of 8x10-inch glossy RC paper. The print should be as sharp as possible, using the optimum aperture of the enlarging lens, focused accurately and with the appropriate precautions to minimize enlarger vibration and film waviness. The print should show all shadow and highlight details, so that they can be enhanced or suppressed during digital tonal manipulation.

The second step is to scan the print on a general-purpose flatbed scanner, with a resolution of between 800 and 1,200 spi and preferably using 16-bit depth. The same scanner that resolves 15 lp/mm directly from film can resolve 52 lp/mm through an 8x enlargement of the same 35mm negative and is, consequently, capable of sufficient image resolution.

This method is also able to recover information from overdeveloped or extreme range negatives by scanning two silver prints, made at different print exposure and contrast settings, optimized for either shadow or highlight areas. The two scans may be combined in the photo editing software. With practice, if a print easel is used to accurately locate the prints and the print boundaries are butted against the scanner window edge, the two scanned images will superimpose exactly. These two images can be overlaid and blended together in the photo editing software in a manner analogous to split-grade printing, but with the same computer workload associated with HDR digital manipulation.

This approach produces very good results with inexpensive scanning equipment. It does, however, require extra time to make the initial RC print and so cannot be considered quick. Making an RC print does offer another advantage. It provides a good reference in its own right and can be used to plan the final image manipulations.

**General Scanner Performance**

Fig.11 compares measured scanning resolutions for several scanner systems and techniques. No scanner is able to capture the full film resolution, and in some cases, they barely meet the minimum requirements of the film formats they were made for, but even the most basic scanner is able to retrieve sufficient resolution from large-format negatives. Unfortunately, we have to assume that the dominance of digital camera sales will ultimately have a detrimental effect on scanner development and model release.

## Film Choices for Scanning

You can also consider color film as an image source for monochrome digital prints. This has the advantage that color images can be manipulated and converted to monochrome in new creative ways, opening avenues for self-expression in a monochrome print. An example is shown in the chapter 'MonoLog'. However, before losing oneself in unbounded digital creativity, one should check that this flexibility is not accompanied by resolution, grain and color sensitivity issues. Color transparency film is not an ideal image source for scanning, because transparencies have a restricted subject brightness range (not unlike digital cameras) and an extremely high density range, which makes them demanding to scan.

In the previous edition, we compared the scanning properties of three emulsion types, Ilford Delta 100, XP2 and Fuji Reala, for resolution, grain and tonality. In practice, we found little resolution difference between the 15x enlargements. Overall, the finest resolution was achieved with fine-grain traditional monochrome film. Conversely, when we compared scanned film grain, those from C41 materials were less obtrusive with a softer grain pattern. Taking into consideration the additional flexibility of color negative originals, the assumption that a scanned monochrome negative is the prime choice for monochrome digital imaging is challenged. In practice, any difference in the color response or tonality between films can be equalized using software adjustments in the photo editing software, either on the monochrome image for overall tonality changes, or on the color image, prior to monochrome conversion, to alter the color sensitivity or mimic the effect of on-camera filters.

| image file resolution [ppi] | print resolution [lp/mm] |
|---|---|
| 225 | 3.4 - 4.2 |
| 250 | 3.7 - 4.7 |
| 275 | 4.1 - 5.2 |
| 300 | 4.5 - 5.6 |
| 325 | 4.9 - 6.1 |
| 350 | 5.2 - 6.6 |

We did not take printer resolution for granted when assessing digital capture solutions. The table above shows some measured printer resolutions at different image ppi settings for horizontal and vertical patterns, with the printer set to its maximum driver dpi. With sufficient image ppi, most modern inkjet printers have a capability that exceeds 7 lp/mm, and they can be discounted as a limiting factor for practical image making. Interestingly, applying our spi to lp/mm conversion in reverse, a target print resolution of 5.3 lp/mm requires a minimum of 280 ppi, which is confirmed by the measurements above.

fig.10 From the top, these are examples of a dedicated 35mm and a medium-format film scanner (Nikon), a compact large-format film scanner and a hybrid flatbed scanner (Epson).

| scanner system | advertised sampling rate [spi] | measured resolution [lp/mm] | measured resolution [spi] |
|---|---|---|---|
| film scanner | 3,200 | 32 | 1,700 |
| | 4,000 | 56 | 3,000 |
| | 4,800 | 62 | 3,300 |
| hybrid flatbed | 1,200 | 15 | 800 |
| | 4,800 | 36 | 1,900 |

| alternative scanning technique | | equivalent resolution [lp/mm] | equivalent resolution [spi] |
|---|---|---|---|
| flatbed scan of 8x10 print (35mm enlargement) | 1,200 | 52 | 2,800 |

fig.11 Actual scanner resolutions usually fall short of advertised sampling rates. However, indirectly scanning a print enlargement retrieves far more negative resolution than any direct film scan. For this comparison, each scan was optimally sharpened to maximize image clarity, and the orthogonal resolution was measured at 10% MTF. A subjectively measured extinction resolution, especially along the diagonal axis, is likely to be higher by up to 25%.

## Comparing Final Print Quality

Let's compare analog and digital capture alternatives, using a typical scene (fig.12) with a wide range of detailed textures, smooth tones and man-made objects. A series of photographs were made from the same position with fine-grain monochrome film in a 35mm camera, a medium-format camera and a large-format 4x5 field camera, followed by a digital SLR, each using an equivalent lens at its optimum aperture. The three negatives were scanned, using a hybrid flatbed scanner (4,800 spi), a film scanner or both, and all subsequent image files were printed with the same inkjet printer to create 16x20-inch prints. In addition, a traditional 8x10 and a 16x20-inch darkroom enlargement were made from the 35mm negative. The 8x10-inch enlargement was scanned at 1,200 spi and also printed at 16x20 inches. The 16x20-inch darkroom print was made for comparison purposes. The prints can now be evaluated for fine detail (leaves and tall grass), sharpness (pylon) and grain in smooth tones (sky).

A close examination of the print from the 35mm negative hybrid-flatbed scan (fig.12a) clearly shows that the performance of this capture combination is not adequate to make a detailed print from this film format. A significant improvement using the same negative is made by making an 8x10-inch darkroom print of it first and then scanning it in with a flatbed scanner (fig.12c). Further improvements are seen in the full-scale darkroom print (fig.12d). The dedicated film scanner produces an image of high sharpness and overall contrast (fig.12b), but a close inspection reveals more obvious grain and marginally less detail than the full-scale darkroom print in fig.12d.

A quantum leap in final image quality is seen when using medium-format negative scans (fig.12e&f). Although the film scan (fig.12f) is clearly better than the flatbed scan (fig.12e), both capture rich detail and texture without showing obtrusive grain. Indeed, the film scanner retrieves a level of detail that almost equals the print made from the 4x5 negative scan (fig.12h), which otherwise outperforms all other capture alternatives in this comparison. The print from the digital SLR (fig.12g) has poor resolution, limited by the sensor performance, and it falls behind the best 35mm results, as seen in the blur of leaves and grass. It is, however, virtually grainless at its low ISO setting, and to obtain similar clarity with film, medium or large-format negatives are required.

In conclusion, film is a proven technology and the best method to archive precious images. Film is also a very flexible medium, because it can be printed both traditionally and digitally after scanning. The use of medium or large-format film produces grain-free prints with excellent resolution when using the latest high-resolution hybrid flatbed scanners or dedicated film scanners. A print from a high-resolution scan can reach and exceed the quality of a darkroom enlargement, especially after selective grain reduction and sharpening in the digital domain. As technology continues to improve, digital camera images will increasingly challenge film performance. The flip side is that the same advance in technology also increases digital redundancy and backward compatibilities.

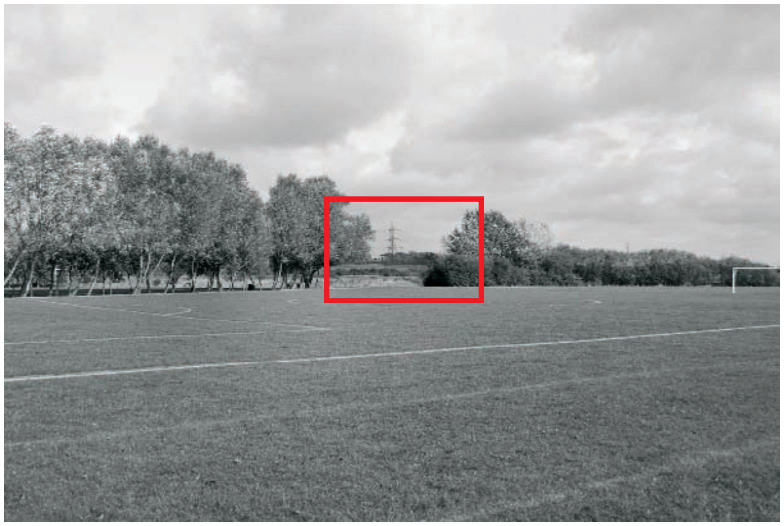
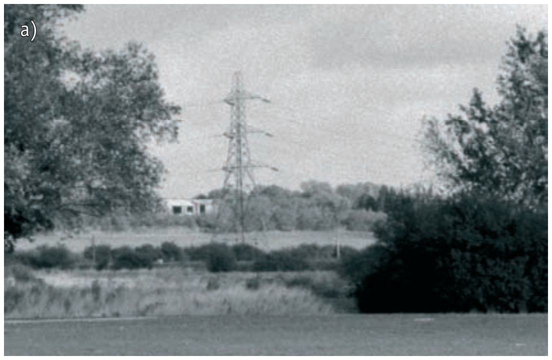


fig.12 This scene was used to compare the relative performance of alternative imaging paths from analog and digital sources. The highlighted area has fine detail, smooth tones and simple well defined structures, which serve to compare the resolution, grain and sharpness in the enlarged samples overleaf.



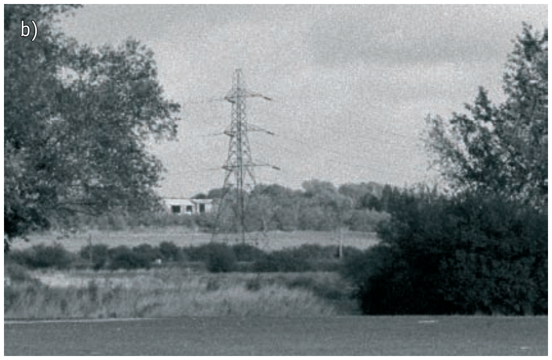
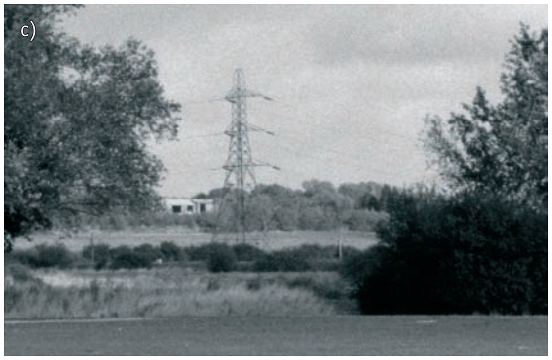


fig.12a 35mm negative,
flatbed scanner

fig.12b 35mm negative,
35mm film scanner



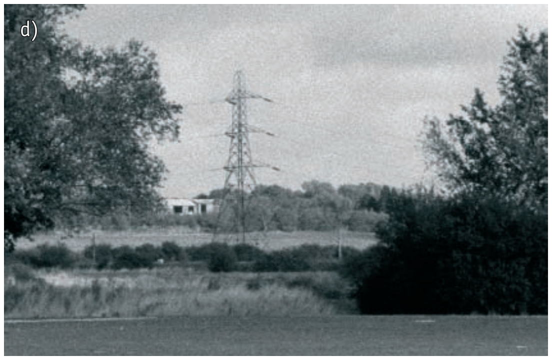
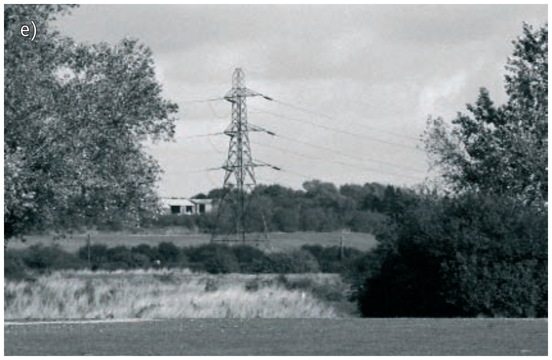


fig.12c 35mm negative,
8x10 enlargement,
flatbed scanner

fig.12d 35mm negative,
16x20 enlargement



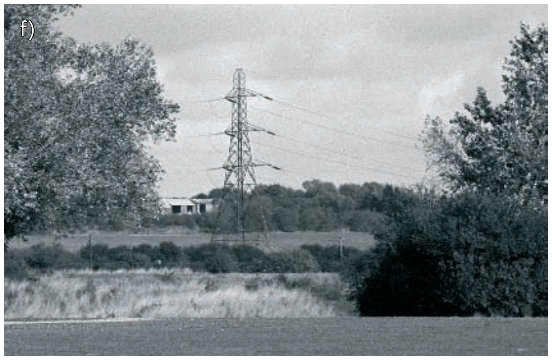
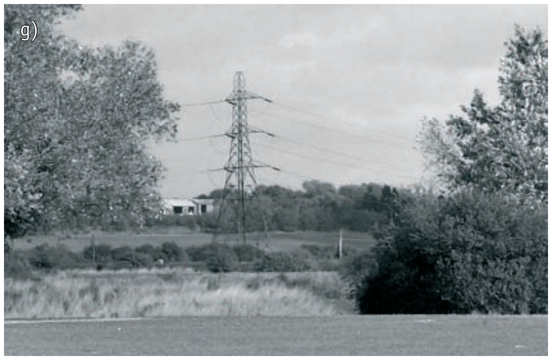


fig.12e 6x7cm negative,
flatbed scanner

fig.12f 6x7cm negative,
medium-format film scanner



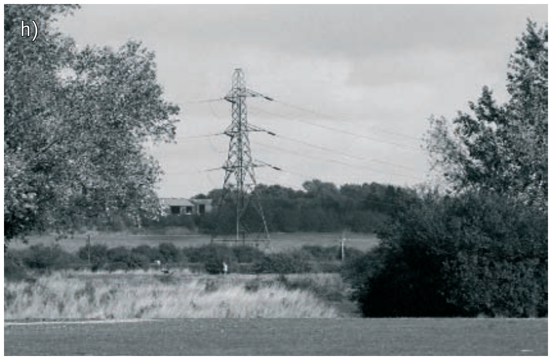


fig.12g 10-Mpixel (DX) digital SLR

fig.12h 4x5-inch negative,
flatbed scanner or
large-format film scanner

### A Few Technical Notes on Image Resolution

It is easy to overlook the degradation to an image brought about by the cumulative effect of individual component resolution losses. As previously mentioned, the Modulation Transfer Factor (MTF) at any particular resolution is the product of the individual MTFs of all optical elements in the imaging path. For instance:

$$MTF_{total} = MTF_{camera\ lens} \cdot MTF_{film} \cdot MTF_{enlarger\ lens} \cdot MTF_{paper}$$

Alternatively, and perhaps more easily calculated, the total resolution (R) of an optical system is related to the individual resolutions of its elements by the following equation:

$$\frac{1}{R^2} = \frac{1}{r_1^2} + \frac{1}{r_2^2} + \ldots + \frac{1}{r_n^2}$$

It is sobering to note, for example, that the combination of a film and lens, each with a resolution of 125 lp/mm, limits the overall performance to just 88 lp/mm. The moral of the story is that, even with relatively poor sensor resolution, one still needs an excellent lens to extract the maximum detail from a subject. For instance, a digital sensor capable of resolving 60 lp/mm by itself is reduced to a system performance of 54 lp/mm when using a 125-lp/mm lens. The above equation also allows us to calculate that a lens that contributes to a combined lens-on-film resolution of 120 lp/mm has a component resolution of 150 lp/mm if the film resolves up to 200 lp/mm.

Given the fact that an image sensor has a known pixel matrix and that digital image capture is independent of additional variables, as in film development, it should be relatively simple to predict the component resolution of the sensor. Proprietary sensor design and capture software algorithms have made this task more difficult than thought. However, the following equations allow for orthogonal and diagonal resolution predictions of practical accuracy:

$$r_{h/v} = \frac{r_s}{2.1}$$

$$r_d = \frac{r_s}{2.6} \cdot \sqrt{2} = \frac{r_s}{1.86}$$

In each case, the sensor's pixel count per unit ($r_s$) is divided by an empirical factor to calculate (or estimate) the actual sensor resolution.

## Review Questions

1. What is the circle of confusion?
    a. a tiny halo around small subject detail caused by lens aberrations
    b. the resolution limit of a particular film format
    c. a blurry circle of the same size as the minimum negative detail
    d. an image imperfection due to diffraction

2. Which of the following increases depth of field?
    a. a smaller aperture setting
    b. a longer focal length from the same position
    c. reduced image magnification
    d. to improve resolution

3. What is the hyperfocal distance?
    a. the max depth of field
    b. the difference between front and rear depth of field
    c. the max focus distance at which the rear depth of field is at infinity
    d. the min focus distance at which the rear depth of field is at infinity

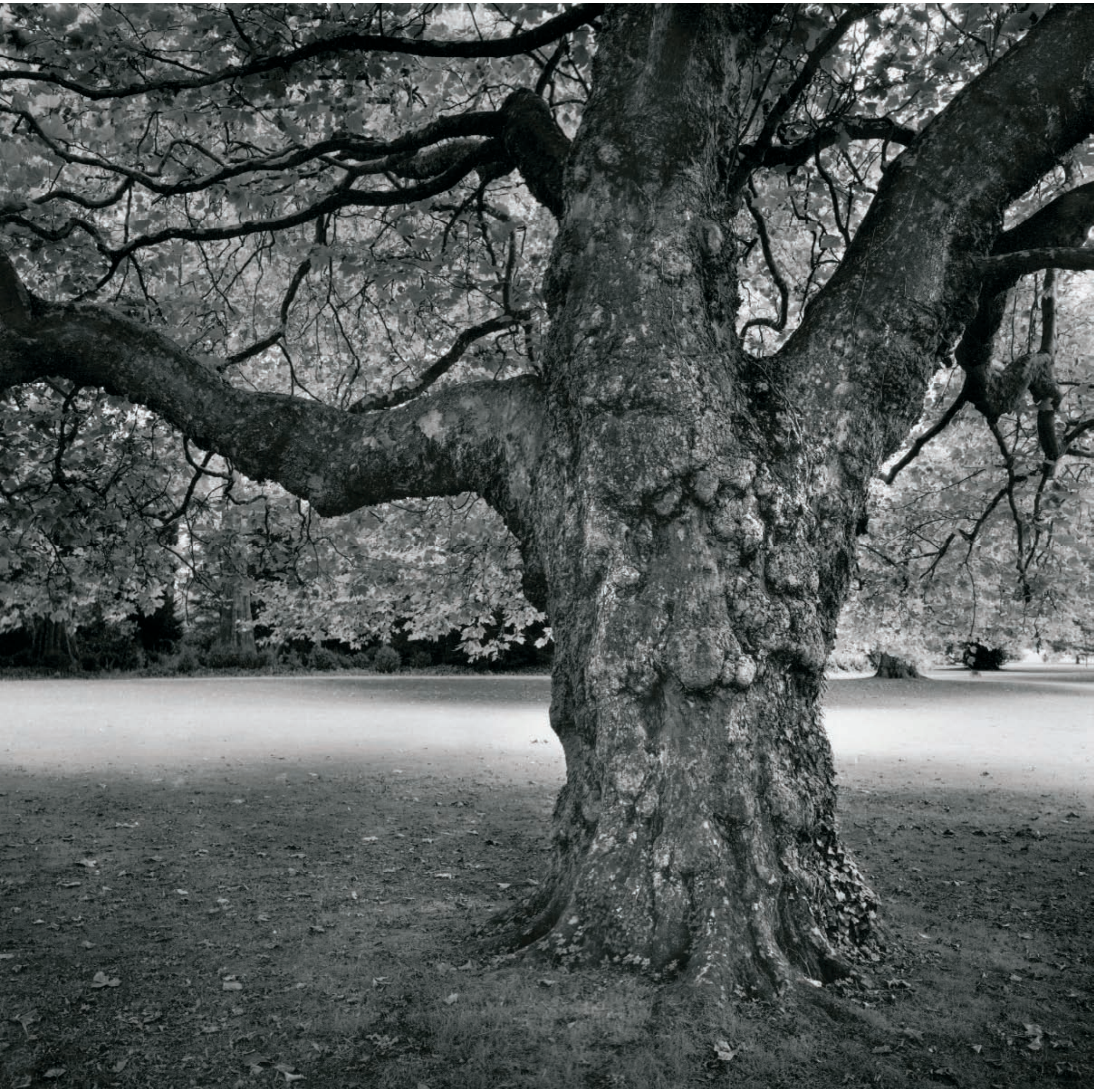
4. Why do all lenses have similar resolution at small aperture settings?
    a. small apertures remove focusing errors
    b. at small apertures, lens aberrations are effectively removed
    c. at small apertures, resolution is limited by diffraction
    d. at small apertures, resolution increases to a maximum

5. What is sharpness?
    a. just another word for contrast
    b. image clarity as a combination of resolution, contrast and acutance
    c. the amount of image detail
    d. just another word for resolution

6. What are the benefits of an MTF graph?
    a. it illustrates the contrast and resolution performance of a lens
    b. clearly shows which is the better of two lenses, all around
    c. provides a single performance value to compare lenses
    d. all of the above

7. Which of the following is true?
    a. the required circle of confusion increases with focal length
    b. the required circle of confusion is independent of film format
    c. the resolution of an optical system is as good as its worst component
    d. the resolution of an optical system is worse than its worst component

1c, 2a, 3d, 4c, 5b, 6a, 7d



© 2006 by Chris Woodhouse, all rights reserved

# Negative Control

This page intentionally left blank

# Introduction to Exposure

## Measuring, controlling and correcting film exposure

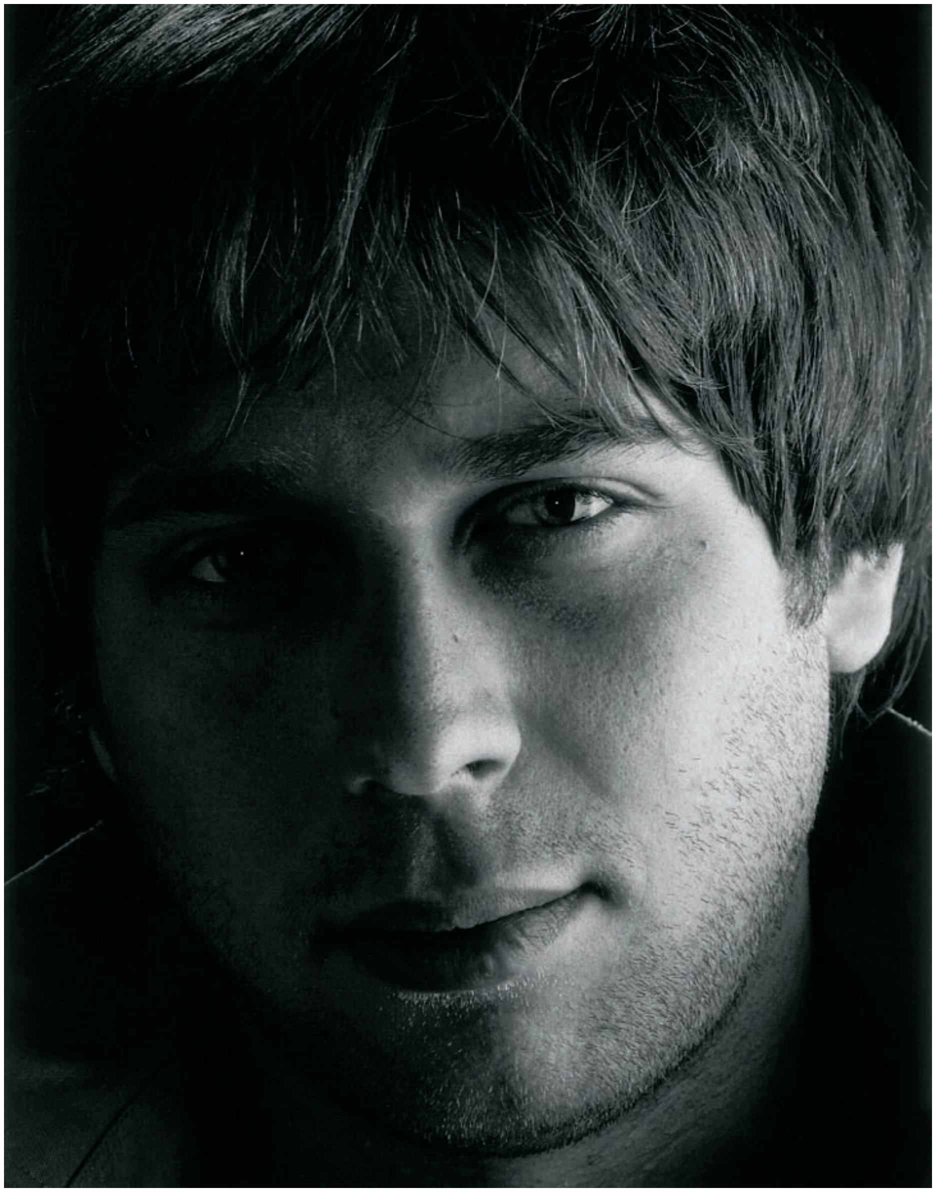
Taking focus and adequate depth of field for granted, film exposure and development are the most significant controls of negative quality. In this chapter, we will cover the fundamentals of film exposure and its control. Film development and a closer look at the Zone System, which combines exposure and development, are covered in following chapters.

Photographic exposure is the product of the illumination and the time of exposure. In 1862, Bunsen and Roscoe formulated the reciprocity law, which states that the amount of photochemical reaction is determined simply by the total light energy absorbed and is independent of the two factors individually. This can be expressed as:

$$H = E \cdot t$$

where 'H' is the exposure required by the emulsion depending on film sensitivity, 'E' is the illuminance, or the light falling on the emulsion, controlled by the lens aperture, and 't' is the exposure time controlled by the shutter. The SI unit for illuminance is lux (lx), and exposure is typically measured in lux-seconds (lx·s). This law applies only to the photochemical reaction and the formation of photolytic silver in the emulsion during exposure. It does not apply to the final photographic effect, which is also controlled by the choice of developer and film processing and is measured in density.

Exposure is largely responsible for negative density. Ultimately, our goal is to provide adequate exposure to the shadows, allowing them to develop sufficient density to be rendered with appropriate detail in the print. In all but a few cases, we have full control over altering H, E or t to balance both sides of the equation. If, for example, a given lighting condition does not provide enough exposure, then a more sensitive film could be



© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50022-3

| film speed [ASA] | aperture [f/stop] | exposure time [1/s] |
|---|---|---|
| 3200 | 2.8 | 1 |
| ·<br>· | ·<br>· | ·<br>· |
| 1600 | 4 | 2 |
| ·<br>· | ·<br>· | ·<br>· |
| 800 | 5.6 | 4 |
| 640<br>500 | ·<br>· | ·<br>· |
| 400 | 8 | 8 |
| 320<br>250 | ·<br>· | ·<br>· |
| 200 | 11 | 15 |
| 160<br>125 | ·<br>· | ·<br>· |
| 100 | 16 | 30 |
| 80<br>64 | ·<br>· | ·<br>· |
| 50 | 22 | 60 |
| 40<br>32 | ·<br>· | ·<br>· |
| 25 | 32 | 125 |
| ·<br>· | ·<br>· | ·<br>· |
| 12 | 45 | 250 |
| ·<br>· | ·<br>· | ·<br>· |
| 6 | 64 | 500 |

fig.1 Rounded-off values for film speed, aperture and exposure times are incremented in stops, so when one is increased and another is decreased by the same factor, the total exposure remains constant.

used, the aperture could be opened to increase the illumination, or the shutter speed could be changed to increase the exposure duration. Illumination and exposure time have a reciprocal relationship, as one is increased and the other decreased by the same factor, the exposure remains constant. Consequently, the law is called the reciprocity law and any deviation from it is referred to as reciprocity failure.

Fig.1 shows a table of standard values for film speed, lens aperture and exposure time. The table uses increments of 1 stop, which reflects a change in exposure by a factor of two. A change of one variable can be easily compensated for by an adjustment in one of the other variables. If, for example, the aperture is closed from f/16 to f/22, then this halving of exposure can be adjusted for by either changing the shutter speed from 1/4 s to 1/2 s or by choosing a film with a speed of ISO 400/27° instead of ISO 200/24°.

Whenever finer increments are required, it is customary to move to 1/3-stop increments. These values are given in the table for film speeds from ISO 25/15° to 800/30°. Manual shutter speed dials are typically not marked in increments this fine, but most electronic shutters are capable of incremental adjustments. Manual 35mm-lens apertures rarely provide increments finer than 1 stop, but many medium-format cameras provide 1/2-stop increments and large-format lenses provide 1/3-stop increments as a standard. Some lightmeters offer readings as fine as 1/10 stop, but this increase in resolution is mostly useful for equipment and material testing and has little value for practical photography. You will find more detail on this subject in the chapters on equipment and 'Quality Control'.

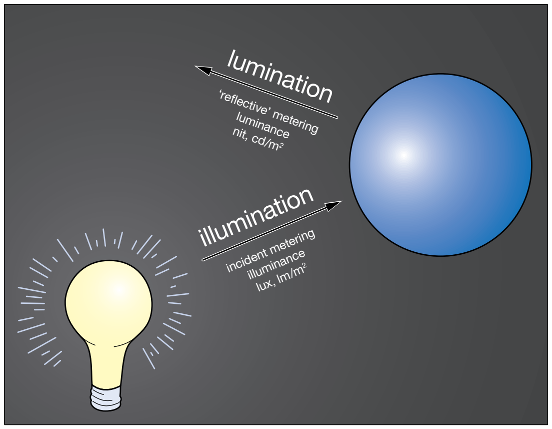


fig.2 Illumination is the light falling onto a surface. It is measured as illuminance 'E' (lux or lm/m²) by an 'incident' lightmeter. Lumination is the light emitted or reflected from a surface, and it is measured as luminance 'L' (nits or cd/m²) by a 'reflected' lightmeter.

## EVs

In 1955, the term exposure value (EV) was adopted into the ISO standard. The purpose of the EV system is to combine lens aperture and shutter speed into one variable. This can simplify lightmeter readings and exposure settings on cameras. EV0 is defined as an exposure equal to 1 second at f/1. Fig.3 provides a table covering typical settings, and with it, a lightmeter EV reading can be translated into a variety of aperture and shutter speed combinations, while maintaining the same exposure. Each successive EV number supplies half the exposure of the previous one, following the standard increments for film speed, aperture and exposure time. This makes EV numbers an ideal candidate to communicate exposures in the Zone System, since zones are also 1 stop of exposure apart from each other.

Most lightmeters have an EV scale in one form or another. Usually, a subject reading is taken and an EV number is assigned to that reading. This EV number can be used for exposure records and an appropriate aperture/time combination can be chosen depending on the individual image requirements. Some camera

$$2^{EV} = \frac{N^2}{t} \quad \Rightarrow$$

$$EV = \frac{\log\left(\frac{N^2}{t}\right)}{\log 2}$$

| EV table | | f/stop | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 1.4 | 2 | 2.8 | 4 | 5.6 | 8 | 11 | 16 | 22 | 32 | 45 | 64 |
| t [1/s] | 1 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| | 4 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| | 8 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| | 15 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| | 30 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| | 60 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| | 125 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| | 250 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| | 500 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |

fig.3 Exposure values (EV) are shorthand for aperture/time combinations to simplify meter readings. The equations on the left show the mathematical relationship, where 'N' is the lens aperture in f/stops, and 't' is the exposure time in seconds.

brands allow for this EV number to be transferred directly to the lens. Aperture ring and shutter-speed settings can then be interlocked with a cross coupling button, and different combinations can be selected, while maintaining a given EV number and constant film exposure. All Hasselblad CF-series lenses feature this convenient EV 'interlock button'.

EVs are shorthand for aperture/time combinations and, therefore, independent of film speed. However, a change in film speed may require a different aperture/time combination and, therefore, a change in EV. As an example, let's assume that a spotmeter returned a reading of EV10 for a neutral gray card, and a moderate aperture of f/8 is chosen to optimize image quality. From fig.3, we see that a shutter speed of 1/15 s would satisfy these conditions. Let's further assume that we would be much more comfortable with a faster shutter speed of 1/60 s, but we don't want to change the aperture. The solution is a change in film speed from ISO 100/21° to 400/27°, where the faster film allows f/8 at 1/60 second. Again from fig.3, we see that this combination is equal to EV12. Changing the film speed setting on the meter from ISO 100/21° to 400/27° will result in a change of measured EV to maintain constant exposure.

Some meters make fixed film speed assumptions while measuring EVs. The Pentax Digital Spotmeter, for example, assumes ISO 100/21 at all times. This meter will not alter the EV reading after a film speed change, and due to its particular design, this does not cause a problem. However, it is important to note that some meters simply return a light value (LV) instead of an exposure value (EV). We can still use their exposure recommendations in form of aperture and shutter speed, but LVs are only numbers on an arbitrary scale, measuring subject brightness, and must not be confused with EVs.

## Reciprocity Failure

Reciprocity law failure was first reported by the astronomer Scheiner in 1889. He found an inefficiency in the photographic effect at relatively long exposure times, common in astronomical photography. Captain W. Abney reported a similar effect in 1894 at extremely brief exposure times, and the astronomer Karl Schwarzschild (1873-1916) was the first to conduct a detailed study on film sensitivity at long exposure times in 1899. To his credit, the deviation from the reciprocity law, due to extreme exposure times, is often referred to as the 'Schwarzschild Effect'.

Strictly speaking, the reciprocity law does not hold at all. Every aperture/time combination, theoretically providing the same exposure, creates a different photochemical reaction, and subsequently, a different negative density. Reciprocity failure can be represented graphically as shown in fig.4. If the reciprocity law held, this graph would give a straight horizontal line, but the actual curve is characterized by a minimum, which corresponds to an optimum illumination and most efficient exposure. At the minimum, the smallest amount of illumination is required to produce a given density. The curve rises at illuminance values above and below the optimum, which indicates that an exposure correction is necessary to achieve the required negative density.

The reciprocity law only applies, within reason, to a limited range of exposure times. Outside of this range, the reciprocity law fails significantly for different reasons. At very brief exposure times, the time is too short to initiate a stable latent image, and at very long exposure times, the fragile latent image partially oxidizes before it reaches a stable state. However, in both cases, total exposure must be increased to avoid underexposure. Schwarzschild amended the equation to calculate exposure to:

$$H = E \cdot t^{p}$$

where 'H' is the exposure, 'E' is the illuminance, 't' is the exposure time, and 'p' is a constant. It was later found that 'p' deviates greatly from one emulsion to the next and is constant only for narrow ranges of illumination. Consequently, it is more practical to determine the required reciprocity compensation for a specific emulsion through a series of tests.

In my type of photography, brief exposure times are rare, but reciprocity failure due to long exposure times are more the rule than the exception. Modern films, when exposed longer than 1/1,000 second or shorter than 1/2 second, satisfy the reciprocity law. Outside of this range, exposure compensation is required to avoid underexposure and loss of shadow detail. Due

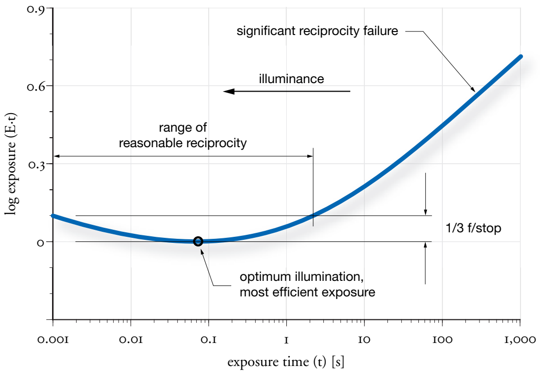


fig.4 The reciprocity law only applies to a limited range of exposure times. Outside of this range, the reciprocity law fails significantly, and an exposure correction is necessary to produce a given negative density.

(graph based on Kodak TMax-400 reciprocity data)

$$reflectance = \frac{luminance}{illuminance}$$

$$r_K = \frac{reflected\ light}{incident\ light}$$

$$r_K = \frac{L}{E} \cdot \pi \quad \left[ \frac{cd/m^2}{lux} \right]$$

All surfaces reflect only a portion of the light that strikes them. The reflection factor '$r_K$' is the ratio of the reflected light to the incident light. Assuming a perfectly diffusing surface, and applying the most commonly used units, the reflection factor can be calculated, using the equation above. This equation also allows conversion between luminance and illuminance, if the reflection factor of the surface is known (Kodak Gray Card = 0.18).

| metered or indicated time | TMax-100 | | TMax-400 | | conventional | |
|---|---|---|---|---|---|---|
| | adjust time | theoretical contrast change | adjust time | theoretical contrast change | adjust time | theoretical contrast change |
| **1s** | **1.3s** | N+⅓ | **1.3s** | N+⅓ | **1.3s** | |
| • | • | | • | | • | |
| • | • | | • | | • | |
| **2s** | **3s** | | **3s** | | **3s** | |
| • | 4s | | 4s | | 4s | |
| • | 5s | | 5s | | 6s | |
| **4s** | **6s** | | **6s** | | **8s** | N+1 |
| • | 7s | | 8s | N+⅔ | 10s | |
| • | 10s | | 11s | | 14s | |
| **8s** | **12s** | | **14s** | | **19s** | |
| • | 15s | N+⅔ | 18s | | 25s | |
| • | 20s | | 24s | | 35s | |
| **15s** | **25s** | | **30s** | | **45s** | |
| • | 35s | | 40s | N+1 | 1m | |
| • | 45s | | 55s | | 1m 30s | |
| **30s** | **1m** | | **1m 10s** | | **2m** | |
| • | 1m 15s | | 1m 30s | | 2m 40s | N+2 |
| • | 1m 30s | | 2m | | 3m 40s | |
| **1m** | **2m 00s** | | **2m 45s** | N+1⅓ | **4m 50s** | |
| • | 2m 30s | | 3m 30s | | 6m 40s | |
| • | 3m 15s | | 4m 45s | | 9m | |
| **2m** | **4m 15s** | N+1 | **6m** | | **12m** | |
| • | 5m 30s | | 8m | | 16m | |
| • | 7m | | 11m | | 22m | |
| **4m** | **9m** | | **14m** | N+1⅔ | **30m** | |
| • | 12m | | 18m | | 41m | |
| • | 15m | | 25m | | 55m | N+3 |
| **8m** | **20m** | | **32m** | | **1h 15m** | |
| • | 25m | | 42m | | 1h 40m | |
| • | 32m | | 55m | N+2 | 2h 15m | |
| **15m** | **40m** | N+1⅓ | **1h 10m** | | **3h** | |

fig.5 This reciprocity compensation table provides exposure and development suggestions for several film types. The contrast changes are based on theoretical values and must be verified by individual tests. Make yourself a copy and keep it in the camera bag as a reference.

to their unique design, Kodak's TMax films suffer far less from reciprocity failure than standard emulsions like Delta, FP4 or Tri-X, but they also require exposure increases to maintain optimum negative quality.

Fig.5 shows recommended exposure increases for a few film types. The table is a compilation of suggestions made by John Sexton and Howard Bond, combined with my own test results. The recommendations for conventional film were tested with Ilford's FP4, and I would not hesitate to use them for other conventional grain films. I have used all values up to 4 minutes of metered time and never experienced any significant exposure deviations. They are offered as a starting point for your own tests, but they are likely to work well as is. Find the lightmeter indicated exposure time in the left column and increase the exposure time to the 'adjusted time' of the film type in question. Adjusted times above one hour must be reviewed with caution. Few lighting conditions are constant over such a long period of time.

Fig.5 is based on the preferred method of compensating for reciprocity failure with increased exposure time. Of course, using an increased lens aperture could be an option too. It might even be easier, when final exposure times are between 1 and 2 seconds, which are hard to time accurately. However, in general, it doesn't solve the problem, it just changes it. Let's say you are using a conventional film, and you need f/22 for the desired depth of field. The lightmeter suggests an exposure time of 30 seconds, and you see from fig.5 that this time has to be increased to 2 minutes in order to compensate for reciprocity failure. This is equivalent to a 2-stop increase, and you might be tempted to just increase the aperture to f/11. This will have two negative effects. First, you will have reduced the depth of field significantly, and that in itself may not be acceptable. Second, the lightmeter will now suggest an exposure time of 8 seconds, and according to fig.5, the reciprocity troubles are far from over. The new exposure still requires an increase in exposure time to 10 seconds, and we have not gained much.

How can this be? Didn't we just compensate for that? No, we didn't. Let's not forget that we are dealing with very long exposure times here. The reciprocity law is no longer applicable. A 2-stop increase in time is not equal to a 2-stop increase in illumination beyond 1 second of exposure time. By increasing illumination, we shortened the exposure time and reduced reciprocity failure, but we did not eliminate it. Using aperture changes instead of exposure time alterations to compensate for reciprocity failure is possible, but it is usually not very practical and would require a different table.

One unwelcome side effect of reciprocity failure and its compensation is a potential increase in negative contrast. This increase in contrast is due to the underexposure of the shadows during reciprocity failure, or an unavoidable overexposure of the highlights when it is compensated for with additional exposure. In other words, when subject illumination is very low, exposure times are long, reciprocity failure is experienced, and shadow densities will suffer first. Fig.5 is designed to take this into account by increasing the exposure time so the appropriate shadow density can be maintained, but the highlight zones will receive this increased exposure too, although they may not need it at all.

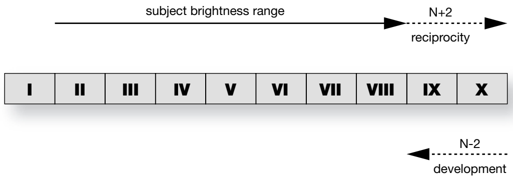


fig.6 In this example, the reciprocity failure compensation has 'saved' the shadow densities, but increased highlight densities to the point that development contraction is required. Development compensations are explained in 'Development and Film Processing'.

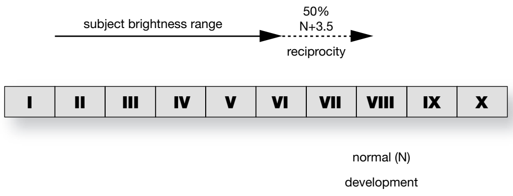


fig.7 In this example, the compensation for reciprocity failure had the welcome side effect of elevating the midtones, and a development expansion to achieve a similar effect is not required.

As you will see in coming chapters, all of my exposure efforts aim for a constant film density in Zone I·5, and all of my film development is customized for Zone VIII·5. According to the Zone System, Zone VIII·5 receives 128 times the exposure of Zone I·5 under normal circumstances. This may be enough illumination for the highlights to experience no reciprocity failure at all, or at least, at a reduced rate. Therefore, the increased exposure time needed for the shadows will cause an overexposure of the highlights, and increased contrast is the result. If the highlights themselves are not affected by reciprocity failure, then every doubling of exposure time will elevate the highlights by one zone and increase the overall contrast by an equivalent of N+1.

All other tonalities are affected to a lesser extent. As a rule of thumb, Zones I to III will need the entire exposure increase to compensate for reciprocity failure and do not experience a contrast increase. Zones IV to VI will use half of the exposure towards compensation and the rest will elevate each zone by half a stop per exposure doubling. Finally, Zones VII to IX will receive one full zone shift for every exposure time doubling involved, because reciprocity correction is not needed for the highlights. These tonal shifts must be considered when overall zone placement is visualized during regular Zone System work.

Let's use the previous example again, where reciprocity failure of a conventional film required an exposure time increase from 30 seconds to 2 minutes. In this case, the shadows needed the additional 2 stops of exposure to maintain adequate negative density, but as seen in fig.6, the highlights did not need the exposure and will develop unnaturally dense. This is reflected in the 'contrast change' column by the term 'N+2'. The only remedy available to compensate for this increase in contrast is a decrease in development time in order to keep highlight densities down. Fig.5 provides information on how much contrast compensation is required, but the details of contrast control through development and its practical application will be discussed in the next chapter.

The next example, fig.7, will illustrate another situation. Let's say we are inside a dark church on a dull day and the lighting is so poor that the meter indicates a 15-minute exposure at the selected aperture. The camera is loaded with FP4, and fig.5 suggests an exposure time increase to 3 hours. From the contrast column, we get the information that image highlights will receive about 3.5 doublings of exposure, but in this example, the scene does not have any highlights. The lightest part of the image is a light gray wall falling onto Zone VI, and therefore, only about half of the contrast increase will have an effect elevating the wall to a low Zone VIII. This situation may fit our visualization of the scene well and we decide that no contrast compensation is required.

Eastman Kodak claims that their TMax films do not require any contrast compensation due to reciprocity failure. Ilford's tests with FP4 revealed a slight contrast increase, but far less than the theoretical values in fig.5. This can be explained with the fact that many film emulsions have fast (toe) and slow (shoulder) components, which are responsible for different parts of the characteristic curve. These components fail the reciprocity law to different degrees and the theoretical values in fig.5 are, therefore, most likely overstated. They should be verified through individual film/developer tests.

## Contrast Control

Negative contrast is typically controlled with film development. However, for very long exposure times, there is a simple technique to reduce the subject brightness range and avoid excessive negative contrast by selectively manipulating the exposure itself.

When composing a low light level or nighttime scene, the light source itself can become part of the image. A street light, a light bulb or even the moon are part of the scene and are so bright, compared to the rest of the image zones, that they end up ruining the image with severe flare or are burned out beyond recognition. For this reason, I carry a simple black card as seen in fig.8 in my camera bag. It can be made from thick cardboard or thin plastic sheeting, but it should be made from matt black material. Use it to dodge the light source during a portion of the film exposure time. I practice the process, while either looking through the viewfinder or onto the ground glass, until I feel confident enough to cover the area in question with the card at arm's length. During the actual exposure, the card is constantly in motion to avoid any telltale signs, much like when dodging a print in the darkroom. Covering the light source for half the exposure time will lower it by one zone. This is not an accurate procedure, and it is one instance where I bracket my exposures.

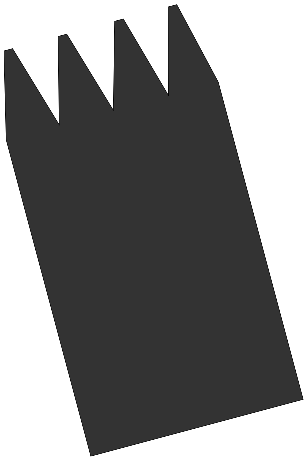


fig.8 A card can be used to dodge bright highlights during very long exposures.

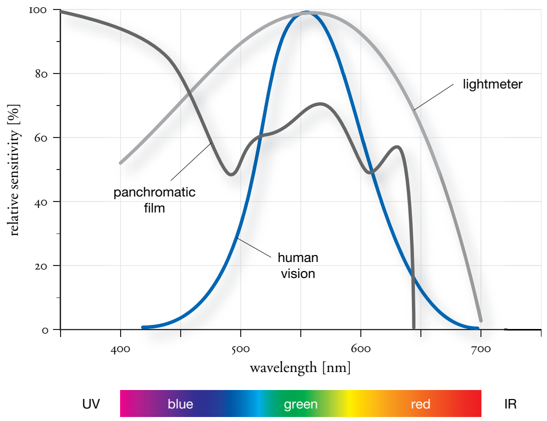


fig.9 Eyes, equipment and materials, all with different spectral sensitivities, are involved in the photographic process. This can make realistic tonal rendering a hit-or-miss operation.

## Spectral Sensitivity

Electromagnetic radiation, ranging in wavelength from about 400-700 nm, to which the human eye is sensitive, is called light. One often overlooked source of unexpected results in monochrome photography is the fact that our eyes, lightmeters and films have unmatched sensitivities to these different wavelengths of the visible spectrum. Fig.9 combines a set of idealized curves showing the typical spectral sensitivities of the human eye, the silicon photo diode, as used in the Pentax Digital Spotmeter, and a typical panchromatic film.

Our eyes have their peak sensitivity at around 550-560 nm, a medium green. This sensitivity diminishes towards ultraviolet and infrared at about the same rate, following a normal distribution and forming a bell curve. Lightmeters depend on light sensitive elements and are, as of this writing, mostly made of either silicon or selenium. Unfortunately, the sensitivities of their diodes and cells do not accurately simulate human vision, because they are more sensitive towards blue and red than the eye.

Film technology has come a long way since its early days. The first emulsions were only sensitive to ultraviolet (UV) and blue light. Improvements led to the introduction of orthochromatic materials, which are also sensitive to green light, but are still blind to red. Portraits as late as the 1930s show people with unnaturally dark lips and skin blemishes as a result. Eventually, the commercialization of panchromatic film in the 1920s offered an emulsion that is sensitive to all colors of light. These films have the ability to give gray tone renderings of subject colors closely approximating their visual brightness, but despite all efforts, panchromatic emulsions still have a high sensitivity to blue radiation. UV radiation, however, is less of a concern, because any glass in the optical path, as in lenses, filters out most of it.

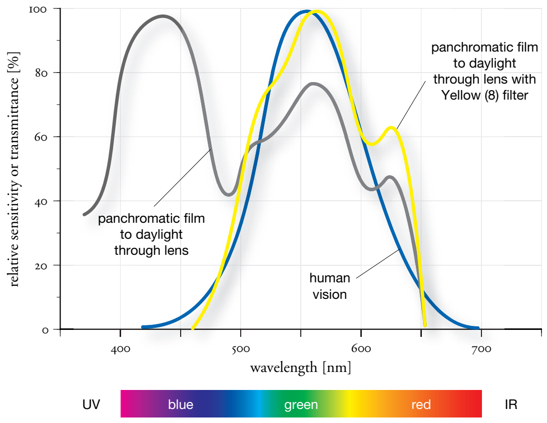


fig.10 A Yellow (8) filter absorbs most of the blue light, enabling panchromatic film to closely match the spectral sensitivity of human vision to daylight.

Have you ever had a print in which the sky appears to be much lighter than you remember it? Fig.9 offers a potential explanation. The eye is far less sensitive towards blue than the film is. What we see as a dark blue sky, the film records as a much lighter shade of gray, minimizing contrast with clouds and often ruining the impact in scenic photography.

Again from fig.9, we see that lightmeters are more sensitive towards red than film is. Using a spotmeter, taking a reading of something predominately red and placing it on a particular zone may render it as much as one zone below anticipation.

I have tested the Pentax Digital Spotmeter and the Minolta Spotmeter F for spectral sensitivity on Ilford FP4. Both gave excellent results for white, gray and yellow material, matched green foliage within 1/3 stop, but rendered red objects as much as 1 stop underexposed. This test result is likely to change using different emulsions, and it becomes clear that matching the spectral sensitivity of lightmeters and films is a rather complex, if not impossible, task. Unless both can be manufactured to match the spectral responses of the human eye, realistic tonal rendering of colored objects will persist to be a bit hit-or-miss.

## Filters

Filters provide useful control over individual tonal values at the time of exposure. They are used either to correct to the normal visual appearance or to intentionally alter the tonal relationship of different subject colors, providing localized contrast control. Filters are made from gelatin, plastic or quality optical glass and contain colored dyes to limit light transmission to specific wavelengths of light.

The total photographic effect obtained through filtration depends on the spectral quality of the light source, the color of the subject to be photographed, the spectral absorption characteristics of the filter and the spectral sensitivity of the emulsion. A filter lightens its own color and darkens complementary colors. A red filter appears red because it only transmits red light; most of the blue and green light is absorbed or filtered out. A blue object will record darker in the final print if exposed through a yellow filter, while a yellow object will record slightly lighter through this filter.

Filters are made for various purposes, but we will concentrate on a few color correction and contrast control filters, which are key to monochromatic photography. To specify filters accurately, we will refer to

Kodak's Wratten numbers in addition to the filter color. I consider the use of four filters to be essential, namely Yellow (8), Green (11), Orange (15) and Red (25).

Yellow (8) absorbs all UV radiation and is widely used to correct rendition of sky, clouds and foliage with panchromatic materials. Fig.10 shows how it closely matches the color brightness response of the eye to outdoor scenes, slightly overcorrecting blue sky. Green (11) corrects the color response to match visualization of objects exposed to tungsten illumination and to elevate tonal rendition of foliage in daylight, while darkening the sky slightly. Orange (15) darkens the sky and blue-rich foliage shadows in landscape photography more dramatically than (8) and is also useful for copying yellowed documents. Red (25) has a high-contrast effect in outdoor photography with very dark skies and foliage. It is also used to remove blue in infrared photography.

Since filters absorb part of the radiation, they require exposure increase to correct for the light loss. Fig.11 provides an approximate guide for popular monochromatic filters in daylight and tungsten illumination. You can perform your own tests by using this table as a starting point and a Kodak Gray Card. First, take a picture of the card without a filter. Then, with the filter in place, expose in 1/2 or 1/3-stop increments around the recommended value. A comparison of the negatives will guide you to which is the best exposure correction.

As a last suggestion, take all light readings without a filter in place, and then, apply the exposure correction during exposure. Filters will interfere with the lightmeter's spectral sensitivity, and incorrect exposures may be the result.

## Lens Extension

When a lens is focused at infinity, the distance between lens and film plane is equal to the focal length of the lens. As the lens is moved closer to the subject, it must be moved farther from the film plane to keep the subject in focus. While this increases subject magnification, it also causes the light entering the lens to be spread over a larger area, reducing the illumination. To compensate for the reduction in illumination, the exposure must be increased.

The f/stop markings on the lens are only accurate for infinity focus, but the light loss is negligible within the normal focusing range of the lens. Up to a subject magnification of about 1/10, the effect is smaller than 1/3 stop. However, for lens-to-subject distances of less than 10 times the focal length, exposure correction is advisable.

The subject magnification (m), the exposure correction factor (e) and the required f/stop exposure correction (n) can be calculated as:

$$m = \frac{v}{u} = \frac{v}{f} - 1 = \frac{f}{u - f}$$

$$e = \left(\frac{v}{f}\right)^2 = (m+1)^2$$

$$n = \frac{\log(m+1) \cdot 2}{\log 2}$$

where 'v' is the lens or bellows extension (the distance between film plane and the rear nodal plane of the lens), 'u' is the lens-to-subject distance (the distance between front nodal plane of the lens and the focal plane) and 'f' is the focal length of the lens.

The rear nodal plane is the location from which the focal length of a lens is measured. Depending on lens construction, the rear nodal plane may not be within the lens body. In true telephoto lenses, it can be in front of the lens. In SLR wide-angle lenses, which need to leave enough room for a moving mirror, it is behind the lens. To determine the location of the rear nodal plane with sufficient accuracy for any lens, follow this procedure:

1. Either set the lens to infinity, or focus the camera carefully on a very distant object. Never point the camera towards the sun!
2. Estimate the location of the film plane and measure a distance equal to the focal length towards the lens.
3. The newly found position is the location of the rear nodal plane at infinity focus.

As the lens is moved further away from the film plane to keep the subject in focus, the rear nodal plane moves with it and can be used to accurately measure the lens extension.

The most convenient ways to correct the exposure for lens extension are to use the f/stop exposure correction (n) to open the lens aperture or to extend shutter

| filter | daylight | tungsten |
|---|---|---|
| Yellow (8) | + 2/3 | + 1/3 |
| Green (11) | + 2 | + 1 2/3 |
| Orange (15) | + 1 1/3 | + 2/3 |
| Red (25) | + 3 | + 2 1/3 |

fig.11 These are recommended exposure corrections in stops for key B&W filters in daylight and tungsten illumination.

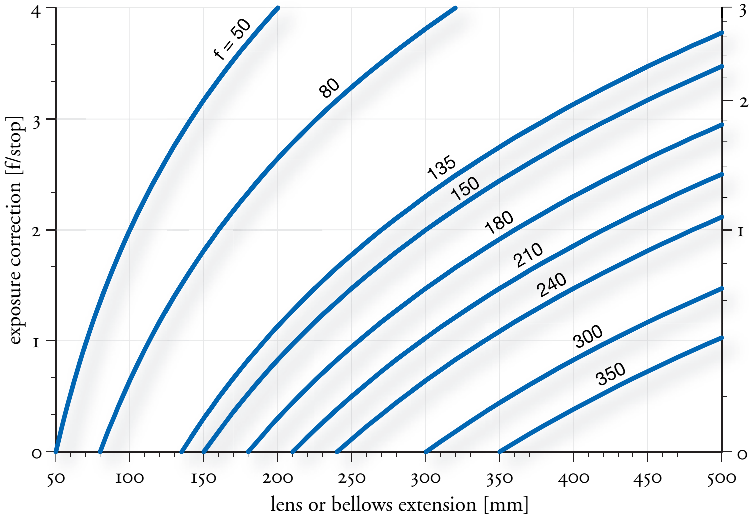


fig.12 (top) Lens or bellows extensions enable subject magnification, but they require an exposure correction depending on focal length of the lens. Many common focal lengths are shown here, and others may be interpolated. Find the intersection of focal length and measured lens extension to determine subject magnification and exposure correction. Then, open lens aperture or extend shutter exposure to compensate for the loss of illumination at the film plane.

exposure time. Fig.12 is used to estimate the exposure correction depending on lens extension for common focal lengths without requiring any calculations. Find the intersection of focal length and measured lens extension to determine subject magnification and exposure correction in f/stops. Then, open lens aperture or extend shutter exposure to compensate for the loss of illumination at the film plane.

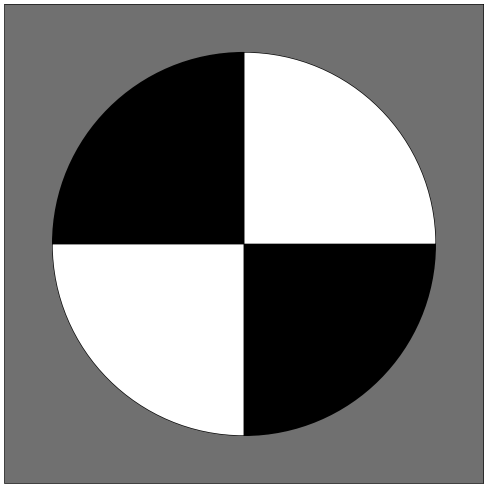
In some cases, it may be undesirable to open the lens aperture or impossible to increase the exposure through the shutter mechanism. The exposure correction factor (e) provides an alternative method. Modify the exposure time by multiplying it by the exposure correction factor, compensating for the loss of illumination at the film plane.

## Bellows Extension

With view cameras, lens extension is referred to as bellows extension. The terminology change is due to a different camera construction, but the principle of exposure correction and the measurements required are still the same. Nevertheless, the relatively large negative format and the fact that the image on the ground glass and film are the same size enable the use of a simple tool. Fig.13 shows a full scale exposure target and its accompanying ruler. Copy the target (left) and the ruler (right) for your own use. Laminate each with clear tape to make them more durable tools.

The next time you create an image and the subject distance is less than 10 times the focal length, place the target into the scene to be photographed. Measure the diameter of the circle on the ground glass with the ruler, reading off subject magnification and the required f/stop correction. Adjust the exposure by either opening the lens aperture or extending the exposure time accordingly.

Technically speaking, perfect exposure ensures that the film receives the exact amount of image-forming light to make a perfect negative. Manual exposure control, using handheld lightmeters combined with visualization techniques like the Zone System, is a slow pursuit and not applicable for every area of photography. On the other hand, fully automatic exposure systems yield a high percentage of accurate exposures with average subjects but remove much individualism and creative control. It is the photographer's decision when to use which system.



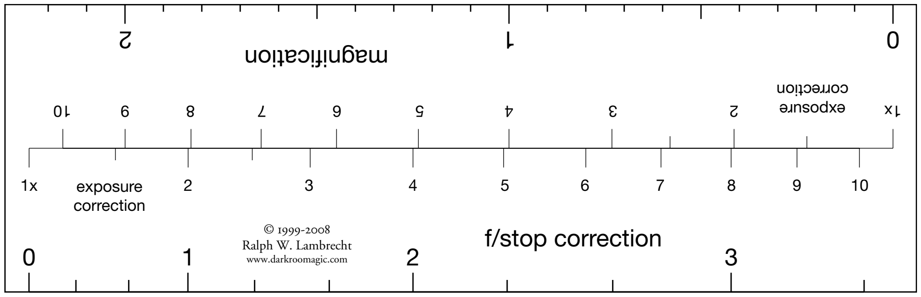
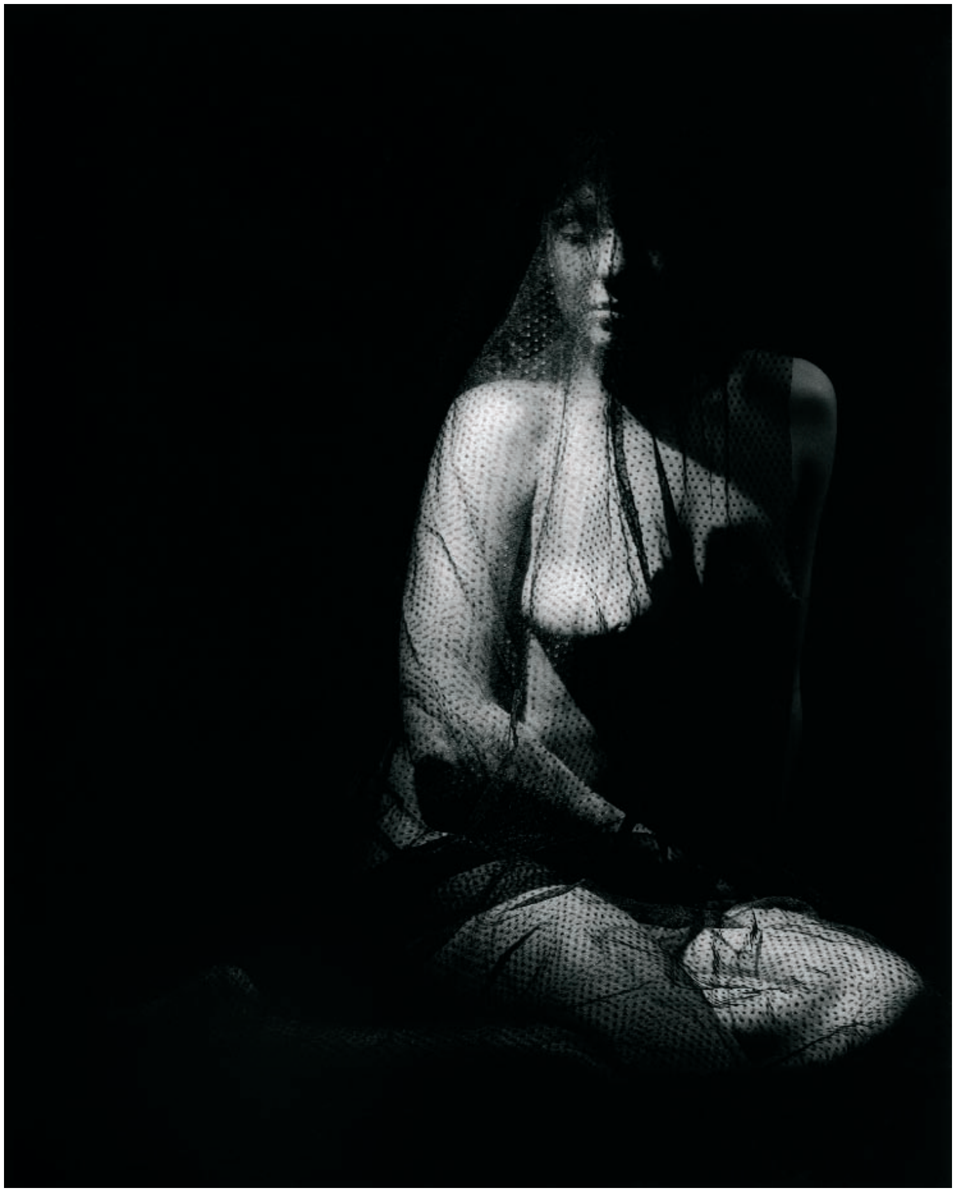


fig.13 View camera owners, copy the target (left) and the ruler (above) for your own use. Laminate each piece with clear tape to make a more durable tool. For close-up photography, place the target into the scene, and measure the diameter of the circle on the view screen with the ruler. Determine subject magnification and f/stop correction to adjust exposure by opening lens aperture or extend shutter exposure.

# Development and Film Processing

## Controlling negative contrast and other film processing steps



Film development is the final step to secure a high-quality negative. Unlike print processing, we rarely get the opportunity to repeat film exposure and development, if the results are below expectations. In order to prevent disappointment, we need to control film processing tightly. Otherwise, fleeting moments can be lost forever. Once film exposure and development is mastered, formerly pointless manipulation techniques become applicable and, in combination with the Zone System, offer the possibility to manage the most challenging lighting conditions. Many photographers value the negative far higher than a print for the fact that multiple copies, as well as multiple interpretations of the same scene, are possible from just one negative. The basic chemical process is nearly identical to the paper development process, which was covered in some detail in 'Archival Print Processing', but a comprehensive understanding is important enough to warrant an additional, brief overview.

### Film Processing in General

The light reaching the film during exposure leaves a modified electrical charge in the light sensitive silver halides of the emulsion. This change cannot be perceived by the human eye and is, therefore, referred to as a 'latent image', but it prepares the emulsion to respond to chemical development. Chemical development converts the exposed silver halides to metallic silver; however, unexposed silver halides remain unchanged. Highlight areas with elevated exposure levels develop more metallic silver than shadow areas, where exposure was low. Consequently, highlight areas develop to a higher transmission density than shadows, and a negative image can be made visible on the film through the action of the developer. For this negative to be of practical use, the remaining and still light sensitive silver halides must be removed without

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50023-5

affecting the metallic silver image. This is the essential function of the fixer, which is available either as sodium or ammonium thiosulfate. The fixer converts unexposed silver halide to soluble silver thiosulfate, ensuring that it is washed from the emulsion. The metallic silver, creating the negative image, remains. Fig.1 shows our recommendation for a complete film processing sequence, which is also a reflection of our current developing technique.

## Developers and Water

The variety of film developers available is bewildering, and writing about different developers with all their advantages or special applications has filled several books already. *The Darkroom Cookbook* by Steve Anchell is full of useful formulae, and is my personal favorite. The search for a miracle potion is probably nearly as old as photography itself, and listening to advertising claims or enthusiastic darkroom alchemists, is not about to end soon. However, I would like to pass along a piece of advice, given to me by C. J. Elfont, a creative photographer and author himself, which has served me well over the years. ‘Pick one film, one developer, one paper and work them over and over again, until you have a true feeling for how they work individually and in combination with each other.’ This may sound a bit pragmatic, but it is good advice, and if it makes you feel too limited, try two each. The point is that an arsenal of too many material alternatives is often just an impatient response to disappointing initial attempts or immature and inconsistent technique. Unless you thrive on endless trial and error techniques, or enjoy experimentation with different materials in general, it is far better to improve craftsmanship and final results with repeated practice and meticulous record keeping for any given combination of proven materials, rather than blaming it possibly on the wrong material characteristics. There are no miracle potions!

Nevertheless, film developer is a most critical element in film processing. A recommendation, based on practical experience, is to begin with one of the prepackaged standard film developers like ID-11, D-76 or Xtol and stick to a supplier proposed dilution. This offers an appropriate compromise between sharpness, grain and film speed for standard pictorial photography. Unless you have reason to doubt your municipal water quality or consistency, you should be

| processing step | | time [min] | film processing | comments |
|---|---|---|---|---|
| 0 | Pre-Soak | 3 - 5 | Prepare the film with an optional water soak at processing temperature. | A water soak prior to film development brings processing tank, spiral and film to operating temperature. It also enables and supports even development with short processing times. |
| 1 | Developer | 4 - 16 | Develop in inversion tank at constant agitation for the first minute, then give 3-5 inversions every 30 seconds for the first 10 minutes and once a minute thereafter. Alternatively, develop in film processor with constant agitation. Control the developer temperature within 1°C, and use the developer one-time only, or track developer activity for consistent development. | After filling with developer, tap tank bottom against a solid surface to dislodge any air bubbles. Development time is dictated by the negative density required for the highlights and varies with film, developer, processing temperature, rate of agitation and water quality. Supplier recommendations can serve as a starting point, but precise development times must be obtained through individual film testing. Times below 4 minutes can cause uneven development, but negative fog density increases with development time. A consistent regime is important for consistent results. Only the exposed portion of the original silver-halide emulsion is reduced to metallic silver during the development of the negative. The remaining, unexposed and still insoluble portion of the silver halide impairs both the immediate usefulness of the negative and its permanence and, hence, must be removed. |
| 2 | Stop Bath | 1 | Use at half the supplier recommended strength for paper and agitate constantly. Relax temperature control to be within 2°C of developer temperature until wash. | The stop bath is a dilute solution of acetic or citric acids. It neutralizes the alkaline developer quickly and brings development to a complete stop. However, the formation of unwanted gas bubbles in the emulsion is possible with film developers containing sodium carbonate. This is prevented with a preceding water rinse. |
| 3 | 1st Fix | 2 - 5 | Use sodium or ammonium thiosulfate fixers without hardener at film strength. Agitate constantly or every 30 seconds in inversion tank. Use the shorter time for conventional films and rapid fixers, and the longer time for modern T-Grain emulsions or sodium thiosulfate fixers. Monitor silver thiosulfate levels of 1st fix to be below 3 g/l, or use fresh fixer every time. Always use fresh fixer for 2nd fix. | In the fixing process, residual silver halide is converted to silver thiosulfate without damaging the metallic silver of the image. The first fixing bath does most of the work, but it is quickly contaminated by the now soluble silver thiosulfate and its complexes. Soon the entire chain of complex chemical reactions cannot be completed successfully, and the capacity limit of the first fixing bath is reached. A fresh second bath ensures that all silver halides and any remaining silver thiosulfate complexes are rendered soluble. Fixing time must be long enough to render all residual silver halides soluble, but extended fixing times are not as critical as with papers. The conventional test to find the appropriate time for any film/fixer combination in question is conducted with a sample piece of film, which is fixed until the film clears and the clearing time is doubled or tripled for safety. |
| 4 | 2nd Fix | 2 - 5 | | |
| 5 | Wash | 4 - 10 | Remove excess fixer prior to toning to avoid staining and shadow loss. The choice of toner dictates the washing time. | Excess fixer causes staining and shadow loss with some toners. This step removes enough fixer to avoid this problem. For selenium toning, a brief 4-minute wash is sufficient, but direct sulfide toning requires a 10-minute wash. |
| 6 | Toner | 1 - 2 | For full archival protection, tone for 1 min in sulfide or 2 min in selenium toner and agitate frequently. | Brief toning in sulfide, selenium or gold toner is essential for archival processing. It will convert sensitive negative silver to more stable silver compounds. Process time depends on type of toner used and the level of protection required. |
| 7 | Rinse | 1 | Wash briefly to remove excess fixer and to prolong washing aid life. | Residual fixer or toner contaminate the washing aid and reduce its effectiveness. This step removes enough fixer and toner to increase washing aid capacity. |
| 8 | Washing Aid | 2 | Dilute according to supplier recommendation and agitate regularly. | This process step is highly recommended for film processing. It makes residual fixer and its by-products more soluble and reduces final washing time significantly. |
| 9 | Wash | 12 | Regulate water flow to secure a complete volume exchange once every minute, and relax the temperature control to be within 3°C of developer temperature. Drain the entire tank once every 3 minutes. | The fixed negative contains considerable amounts of fixer together with small, but not negligible, amounts of soluble silver thiosulfate complexes. The purpose of washing is to reduce these chemicals to miniscule archival levels, and thereby significantly improve the stability of the silver image. Film longevity is inversely proportional to the residual fixer in the film. However, traces of residual fixer may actually be helpful in protecting the image. |
| 10 | Drying Aid | 1 | Use a drying aid as directed, or use a mixture of alcohol and distilled water (1+4). | Using distilled or deionized water will leave a clear film base without intolerable water marks. Replacing some water with more readily evaporating alcohol will speed up drying. |

fig.1 Negatives are valuable, because they are unique and irreplaceable. Archival processing, careful handling and proper storage work hand in hand to ensure a maximum negative life expectancy.

able to use it with any developer. However, distilled or deionized water is an alternative, providing additional consistency, especially if you develop film at different locations. Filters are available to clean tap water from physical contaminants for the remaining processing steps, but research by Gerald Levenson of Kodak as far back as 1967 and recently by Martin Reed of Silverprint suggests avoiding water softeners as they reduce washing efficiency in papers.

## Characteristic Curve, Contrast and Average Gradient

Film characteristic curves were briefly introduced in 'Introduction to Sensitometry'. They are used to illustrate material and processing influences on tone reproduction throughout the book. They are a convenient way to illustrate the relationship between exposure and negative density, but it is also helpful to have a quantitative method to evaluate and compare characteristic curves. Over the years, many methods have been proposed, mainly for the purpose of defining and measuring film speed. Several have been found to be inadequate or not representative of modern materials and have since been abandoned. The slightly different methods used by Agfa, Ilford, Kodak, and the current ISO standard are all based on the same 'average gradient' method.

Negative contrast is defined as negative density increase per unit of exposure. Fig.2 shows how the same exposure range can differ in negative density increase according to the local shape of the characteristic curve. In this example, toe and shoulder of the curve have a relatively low increase in density signified by a gentle slope or gradient, and the gradient is steepest in the midsection of the curve. These local gradients are a direct measure of local negative contrast, but a set of multiple numbers would be required to characterize an entire curve.

The average gradient method on the other hand, identifies just two points on the characteristic curve to represent significant shadow and highlight detail, as seen in fig.3. Here a straight line, connecting these two points, is evaluated on behalf of the entire characteristic curve, while fulfilling its function of averaging all local gradients between shadows and highlights. The slope of this line is the average gradient and a direct indicator of the negative's overall contrast. It can be calculated from the ratio a/b, which is the

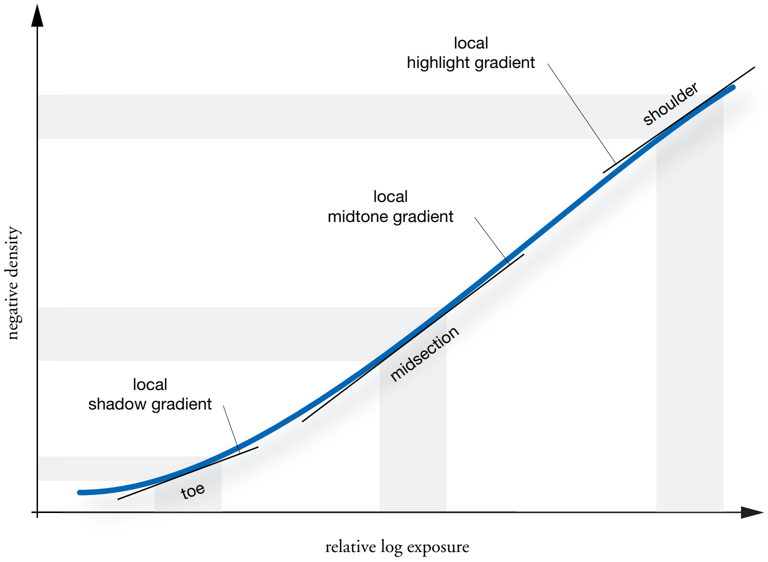


fig.2 Negative contrast is defined as negative density increase per unit of exposure. The same exposure range can differ in negative density increase according to the local shape of the characteristic curve. The local slope, or gradient, is a direct measure of local negative contrast.

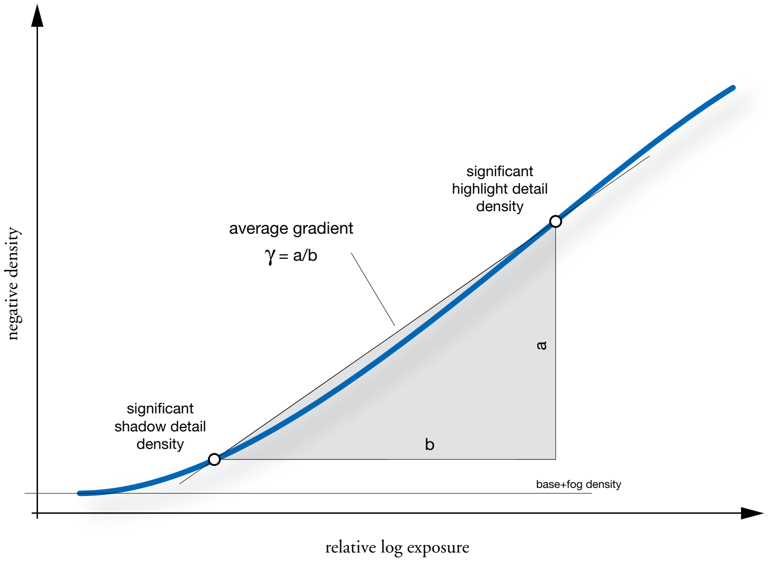


fig.3 The average gradient method identifies two points on the characteristic curve representing significant shadow and highlight detail. A straight line connecting the points is evaluated on behalf of the entire characteristic curve.

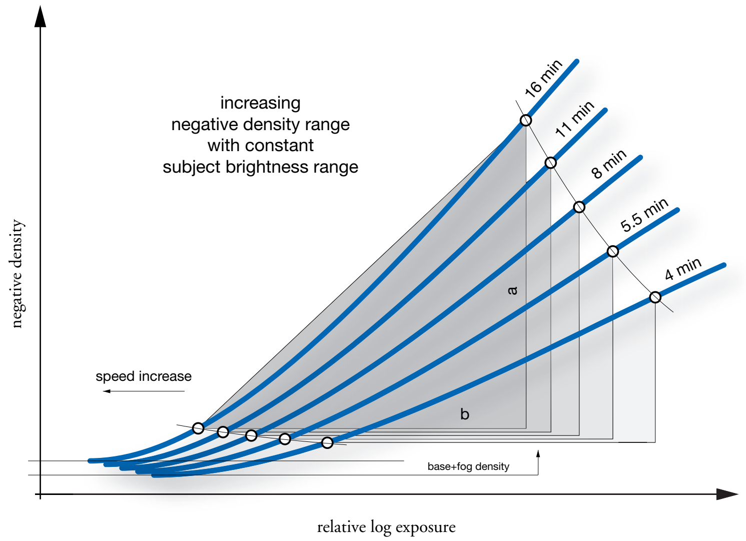


fig.4 Shadow densities change only marginally when development times are altered, but highlight densities change significantly. The average gradient and the negative density range (a) increase with development time, when the subject brightness range (b) is kept constant.

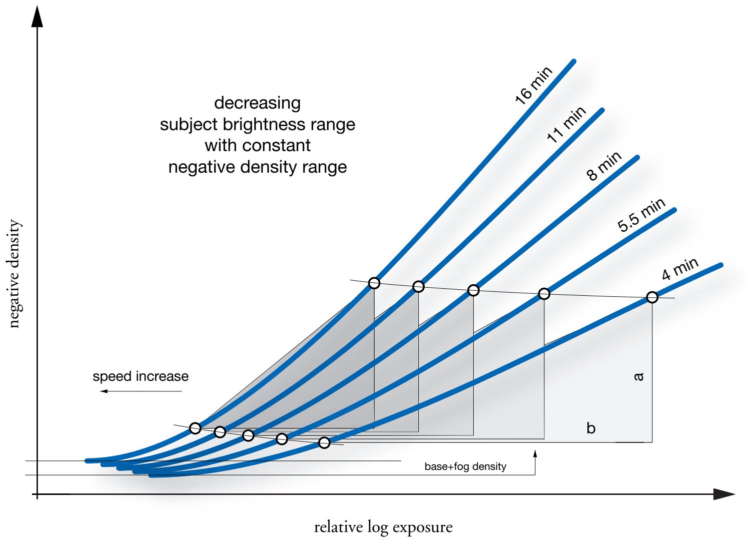


fig.5 The average gradient increases and the subject brightness range (b) decrease with development time, when the negative density range (a) is kept constant.

ratio of negative density range (a) over log exposure difference (b). The average gradient method is universally accepted, but as we will see in the following chapters, the consequences of selecting the endpoints are rather critical and different intentions have always been a source of heated discussion among manufacturers, standardization committees and practical photographers. At the end of the day, it all depends on the desired outcome and in 'Creating a Standard' we define these endpoints to our specifications in compliance with the rest of this book and a practical approach to the Zone System in mind.

## Time, Temperature and Agitation

Exposure is largely responsible for negative density, but film development controls the difference between shadow and highlight density, and therefore the negative contrast. The main variables are time, temperature and agitation, and controlling development precisely requires that these variables be controlled equally well. Data sheets provide starting points for developing times and film speeds, but complete control can only be achieved through individual film testing, as described in detail through following chapters.

Fig.4 shows how the development time affects the characteristic curve when all other variables are kept constant. With increased development time, all film areas, including the unexposed base, increase in density, but at considerably different rates. The shadow densities increase only marginally, even when development times are quadrupled, where simultaneously, highlight densities increase significantly. This effect is most useful to the Zone System practitioner and can be evaluated from the following two aspects.

First, in fig.4 the subject brightness range (b) is kept constant by fixing the relative log exposure difference between shadow and highlight points. We can see how the negative density range (a) and the average gradient increase with development time. Second, in fig.5 the negative density range (a) is kept constant by fixing the negative density difference between shadow and highlight points. This way, we can see how the average gradient increases, but the subject brightness range (b) decreases with development time.

The last observation is the key to the Zone System's control of the subject brightness range by accordingly adjusted film development time. The negative density range is kept constant, allowing to print many lighting conditions on a single grade of paper with ease.

Other paper grades are not used to compensate for difficult to print negative densities anymore, but are left for creative image interpretation.

One important side effect becomes apparent with both figures. The shadow points, having a constant density above base+fog density, require less exposure with increasing development time, or in other words, film speed increases slightly with development. Consequently, film exposure controls shadow density and development controls highlight density, but we must always remember that film speed varies with development time.

The standard developing temperature for film is 20°C. Photographers living in warmer climates often find it difficult to develop film at this temperature and may choose 24°C as a viable alternative. However, development temperature is a significant process variable, and film development time tests must be repeated for different temperatures and then tightly controlled within 1°C. The temperature compensation table in fig.6 gives reasonable development time substitutes for occasional changes in development temperature. Do not underestimate the cooling effect of ambient darkroom temperatures in the winter or the warming effect of your own hands on the inversion tank. The temperature is less critical for any processing step after development. The above tolerance can be doubled and even tripled for the final wash, but sudden temperature changes must be avoided, otherwise reticulation, a wrinkling of the gelatin emulsion, may occur.

Agitation affects the rate of development, as it distributes the developer to all areas of the film evenly, as soon as it makes contact. While reducing the silver halides to metallic silver, the developer in immediate contact with the emulsion becomes exhausted and must be replaced through agitation. Agitation also supports the removal of bromide, a development by-product, which otherwise inhibits development locally and causes 'bromide streaks'.

A consistent agitation technique is required for uniform film development. You can use the recommendations in fig.1 as a starting point, or you can test for proper agitation yourself. Expose an entire negative to a uniform surface placed on Zone VI and develop for the normal time, but using different agitation methods. Increased density along the edges indicates excessive agitation, and uneven or mottled negatives indicate a lack of agitation.

## Normal, Contraction and Expansion Development

Normal development creates a negative of normal average gradient and contrast. A negative is considered to have normal contrast if it prints with ease on a grade-2 paper. An enlarger with a diffused light source fulfills the above condition if the negative has an average gradient of around 0.57. A condenser enlarger requires a lower average gradient to produce an identical print on the same grade of paper. We will discuss other practical average gradient targets in detail in the next two chapters, and a table with typical negative densities for all zones is given in 'Tone Reproduction'.

We saw in fig.5 how the intentional alteration of film development time and average gradient can provide control over the subject brightness range, while maintaining a constant negative density range, which keeps print making from becoming a chore. However, if the alteration is unintentional, then density control becomes a processing error. Film manufacturers have worked hard to make modern films more forgiving to these 'processing errors' and have, in turn, taken some of the tonal control away from Zone System practitioners. Nevertheless, even modern emulsions still provide enough tonal control to tolerate subject brightness ranges from 5-10 stops or more.

| development temperature substitutes | | | | | | |
|---|---|---|---|---|---|---|
| 18°C<br>64°F | 19°C<br>66°F | 20°C<br>68°F | 21°C<br>70°F | 22°C<br>72°F | 23°C<br>73°F | 24°C<br>75°F |
| 4:50 | 4:30 | 4:00 | - | - | - | - |
| 6:00 | 5:30 | 5:00 | 4:40 | 4:10 | - | - |
| 7:15 | 6:40 | 6:00 | 5:30 | 5:00 | 4:30 | 4:10 |
| 8:30 | 7:45 | 7:00 | 6:30 | 5:50 | 5:20 | 4:50 |
| 9:40 | 8:50 | 8:00 | 7:20 | 6:40 | 6:00 | 5:30 |
| 12:10 | 11:00 | 10:00 | 9:10 | 8:20 | 7:40 | 7:00 |
| 14:30 | 13:15 | 12:00 | 11:00 | 10:00 | 9:10 | 8:20 |
| 17:00 | 15:30 | 14:00 | 12:45 | 11:40 | 10:40 | 9:40 |
| 19:20 | 17:40 | 16:00 | 14:40 | 13:20 | 12:10 | 11:00 |
| 21:50 | 19:50 | 18:00 | 16:30 | 15:00 | 13:40 | 12:20 |
| 24:10 | 22:00 | 20:00 | 18:15 | 16:40 | 15:10 | 13:50 |
| 26:40 | 24:15 | 22:00 | 20:00 | 18:15 | 16:40 | 15:10 |

fig.6 The standard developing temperature for film is 20°C. However, this temperature compensation table gives reasonable development time substitutes for occasional changes in development temperature. For example, developing a film for 10 min at 20°C will lead to roughly the same negative densities as developing it for 7 min at 24°C.

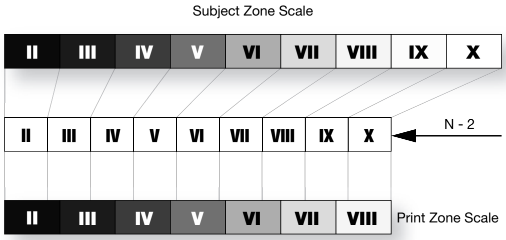


fig.7 In this example, the highlights of a high-contrast scene metered two zones above visualization. N-2 contraction development is used, limiting the highlight densities to print well on grade-2 paper.

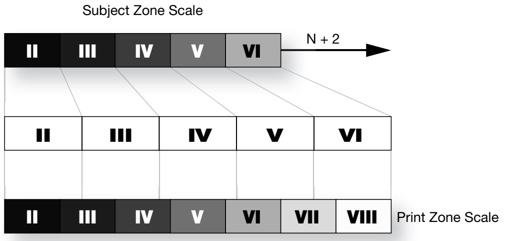


fig.8 In this example, the highlights of a low-contrast scene metered two zones below visualization. N+2 expansion development is used, elevating the highlight densities to print well on grade-2 paper.

In a low-contrast lighting condition, the normal gradient produces a flat negative with too small of a density difference between shadows and highlights, and the average gradient must be increased to print well on normal paper. In a high-contrast lighting condition, the normal gradient produces a harsh negative with a negative density range too high for normal paper, and the average gradient must be decreased. The desired average gradient can be achieved by either increasing or decreasing the development time, but appropriate development times must be determined through careful film testing.

In regular Zone System practice, we measure the important shadow values first and then determine appropriate film exposure with that information alone, thereby placing these shadows on the visualized shadow zone. Then, we measure the important highlight values and let them 'fall' onto their respective zones. If they fall onto the visualized highlight zone, then development is normal. If they fall two zones higher, contraction development of N-2 must be used to keep the highlight from becoming to dense. On the other hand, if they fall two zones lower, expansion development of N+2 must be used

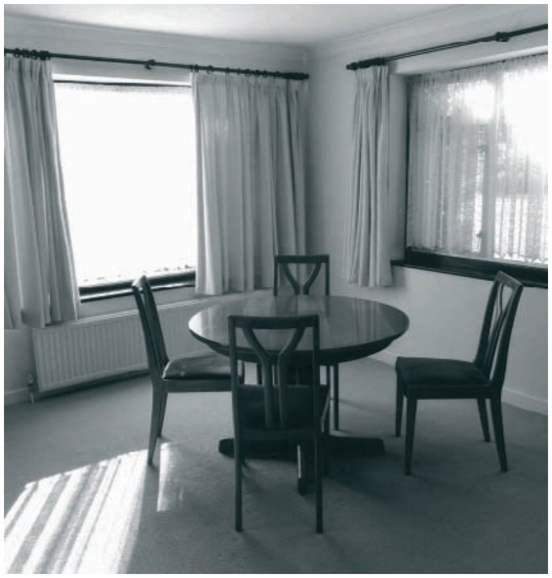


fig.9a (right) In this high-contrast scene, normal film development was not able to capture the entire subject brightness range, and as a result, some highlight detail is lost with grade-2 paper.
(print exposed for shadow detail to illustrate strong negative highlight density)

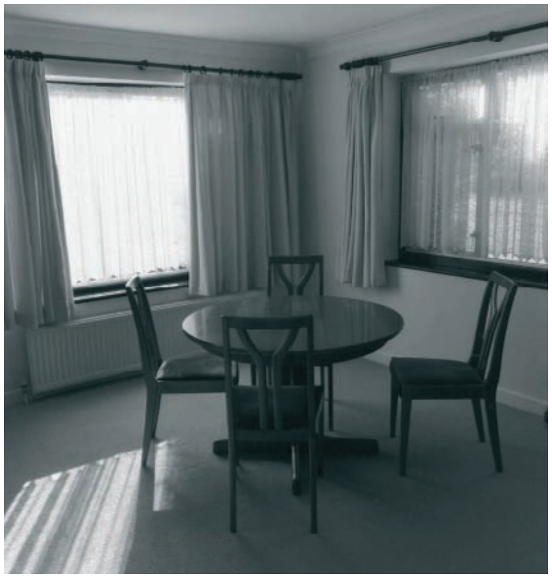


fig.9b (far right) N-2 film development extended the textural subject brightness range by two zones. This reduced the overall negative contrast and darkened midtones but avoided a loss of highlight detail.

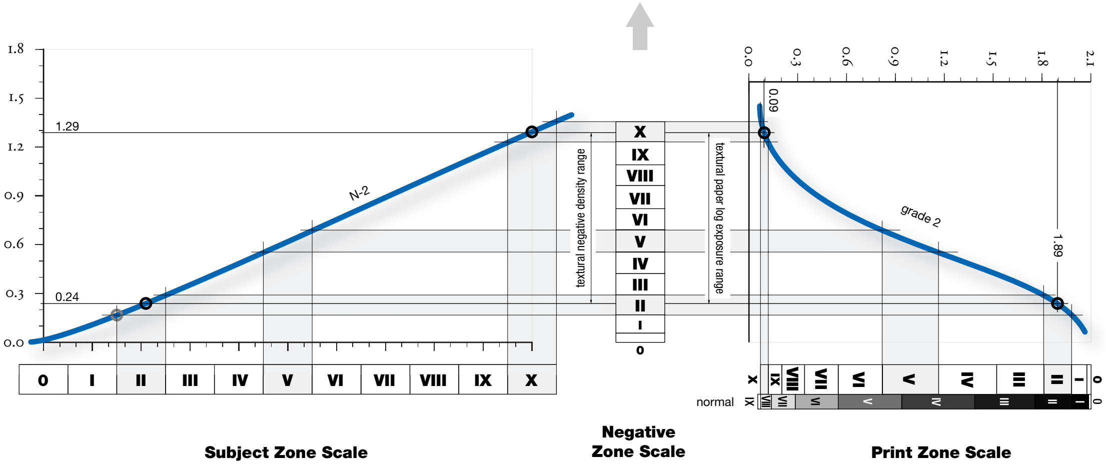


fig.9c N-2 film development is used to increase the subject brightness range captured within the normal negative density range.

to elevate the highlight densities. Fig.7 and fig.8 show how the tonal values change due to contraction and expansion development respectively, and fig.9 and fig.10 illustrate the concept further.

In fig.9a, shadows at the bottom of the table were measured to determine film exposure. The film was developed for a time, previously tested to cover a normal textural subject brightness range of 6 stops. The print was then exposed to optimize shadow density. However, this high-contrast indoor scene had a subject brightness range of 8 stops, far too much for normal development, and consequently, the negative highlight detail was too dense to register on normal grade-2 paper. Fig.9b is from a negative, which received the same exposure, but a contracted N-2 film development reduced highlight densities and allowed for the entire subject brightness range to be recorded on grade-2 paper. This reduced overall negative contrast, darkened midtones and making for a somewhat duller print, but it avoided a loss of highlight detail.

In fig.10a, shadows at the bottom of stairs were measured to determine film exposure. Again, the film was given normal development, and the subsequent print was exposed to optimize shadow density as

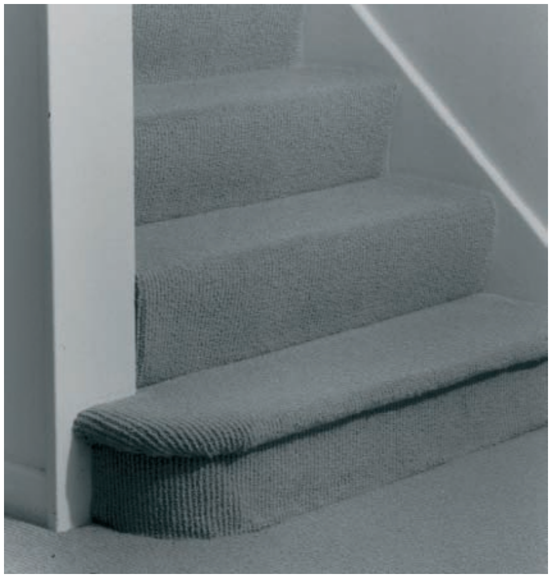


fig.10a (far left) In this low-contrast scene the subject brightness range is small and normal film development will make for a dull print with grade-2 paper. (print exposed for shadow detail to illustrate weak negative highlight density)

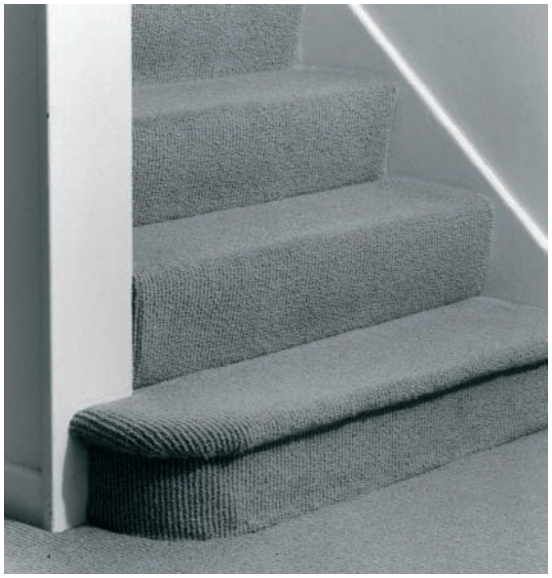


fig.10b (left) N+2 film development elevated highlight densities by two zones, increasing negative and print contrast. The entire negative density range is used.

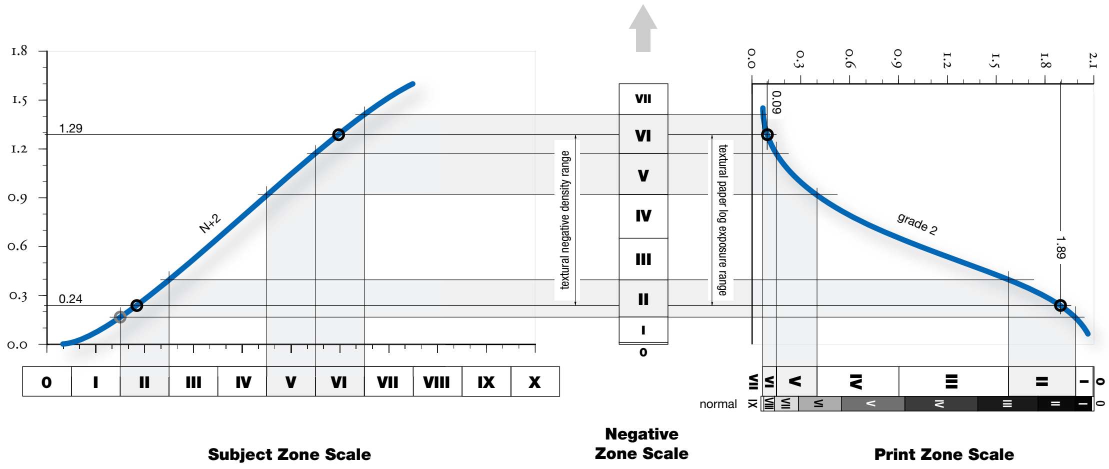


fig.10c N+2 film development is used to decrease the subject brightness range captured within the normal negative density range. Final zone densities depend on the negative and paper characteristic curves, but some trends due to film development are clearly visible in fig.8c and here.

well. This time, the low-contrast scene had a subject brightness range of only 4 stops, and consequently, the negative highlight detail did not gain sufficient density during normal development to show clear white on normal grade-2 paper. Fig.10b is from a negative, which received the same exposure, but an extended N+2 film development increased negative highlight densities, utilizing the entire print density range of grade-2 paper. This increased overall negative contrast, lightened midtones and got rid of muddy and dull highlight detail.

## Optional Processing Steps

Film processing is very similar to print processing. Exposed silver halides are developed to metallic silver, unexposed halides are removed from the emulsion, thereby fixing the image and making it permanent, and finally, the film is washed to remove residual chemicals. Fig.1 shows a complete list of film processing steps that lead to negatives of maximum permanence. Depending on individual circumstances, some of these processing steps are optional, but with the exception of washing aid, when applied on a regular basis, they all must be part of the film-development test.

### Pre-Soak

A water soak prior to film development keeps sheet film from sticking together when placed into the developer and brings processing tank, spiral and film to operating temperature, but it also causes the gelatin in the film's emulsion to absorb water and swell. As a consequence, the subsequent developing bath is either absorbed more slowly, extending the development time, or the wet emulsion promotes the diffusion of some chemicals, reducing the development time.

In general, a pre-soak supports a more even development across the film surface and is, therefore, recommended with short processing times of less than 4 minutes. However, when applied, it must be long enough (3-5 minutes) to avoid water stains. The pre-soak partially washes antihalation and sensitizing dyes from the film. This is harmless and helpful in removing a disturbing pink tint from negatives, but when dyes are washed out, useful wetting agents and possible development accelerators are potentially washed from the film as well. This is another reason why the effect of a pre-soak on development time must be tested for each film/developer combination.

### Stop Bath

The stop bath is a dilute solution of acetic or citric acid. It neutralizes the alkaline developer quickly and brings development to a complete stop. However, unwanted gas bubbles may form in the emulsion with film developers containing sodium carbonate, which will impede subsequent fixing locally.

This is easily prevented with a water rinse prior to the stop bath, or by replacing the stop bath with a water bath. Please note, however, that development will slowly continue in the rinse or water bath until all active development ingredients are exhausted, or the fixer finally stops development altogether. Some darkroom workers see this as an opportunity to enhance shadow detail slightly, and they propose replacing the stop bath with a water bath as a general rule. Their reasoning is that it takes longer to exhaust the developer in areas of low exposure, and thereby, shadows have a longer developing time in the water bath than highlights.

### 2nd Fix

In the fixing process, residual silver halide is converted to silver thiosulfate without damaging the metallic silver of the image. The first fixing bath does most of the work, but it is quickly contaminated by the now soluble silver thiosulfate and its complexes. Soon the entire chain of complex chemical reactions can not be completed successfully, and the capacity limit of the first fixing bath is reached. A fresh second bath ensures that all silver halides and any remaining silver thiosulfate complexes are rendered soluble.

Fixing time must be long enough to render all residual silver halides soluble, but extended fixing times are not as critical with film as they are with papers. The conventional test to find the appropriate time for any film/fixer combination is conducted with a sample piece of film, which is fixed until the film clears and the clearing time is doubled or tripled for safety.

### Toner

It is recommended to file negatives in archival sleeves and keep them in acid-free containers. This way, they are most likely stored in the dark and the exposure to air-born contaminates is minimized, which means that they are normally better protected than prints. Nevertheless, brief toning in sulfide, selenium or gold toner is essential for archival processing. It converts sensitive negative silver to more stable silver compounds. Process time depends on the type of toner used and the level of protection required. Use only freshly prepared toner, otherwise, toner sediments will adhere to the soft emulsion and cause irreparable scratches on our valuable negatives.

Washing the film prior to toning is a necessity, because excess fixer causes staining and shadow loss with some toners. The wash removes enough fixer to avoid this problem. For selenium toning, a brief 4-minute wash is sufficient, but direct sulfide toning requires a 10-minute wash.

### Washing Aid

Applying a washing-aid bath prior to the final wash is standard with fiber-base print processing, and is also recommended for film processing. It makes residual fixer and its by-products more soluble and reduces the final washing time significantly. Washing aids are not to be confused with hypo eliminators, which are not recommended, because they contain oxidizing agents that may attack the image.

Washing aid is one of the few chemicals in film processing that can be used more than once. A brief water rinse prior to its application is recommended; otherwise, residual fixer or toner contaminate the washing aid and reduce its effectiveness. The rinse removes enough fixer and toner to considerably increase washing aid capacity.

## Washing the Film

The basic process of film washing is almost identical to washing prints. However, in many ways, film responds to washing more like an RC print, because in both, the emulsion is directly coated to the plastic substrate and not to an intermediate layer of paper fibers, as with fiber-base prints. This makes film washing unique enough to repeat a few key points about washing, in general, and address the specifics of film washing, in particular.

Previously fixed or selenium toned film contains a substantial amount of thiosulfate, which must be removed to give the negative a reasonable longevity or archival stability. The principal purpose of archival washing is to reduce residual thiosulfate to a specified concentration, known to assure a certain life expectancy. This specification has changed over time. In 1993, ISO 10602 called for no more than 0.007 g/m$^2$ residual thiosulfate in film across the board. The current standard, ISO 18901:2002, differentiates between a maximum residual thiosulfate level of 0.050 g/m$^2$ for a life expectancy of 100 years (LE100) and 0.015 g/m$^2$ for a life expectancy of 500 years (LE500). The new standard, therewith, recognizes the different life expectancies of roll and sheet film, most of which are coated on acetate and polyester substrates, respectively. According to the Image Permanence Institute (IPI), an acetate film base has a life expectancy of only 50-100 years, but a polyester base has a predicted life expectancy of over 500 years. Consequently, the LE500 value is only applicable for polyester-base sheet films, since acetate-base roll films don't last for 500 years.

The old standard assumed that residual thiosulfate levels should be as low as possible. The new standard responds to recent findings, which ironically show that small residual amounts of thiosulfate actually provide some level of image protection. Safe levels of residual thiosulfate vary with the type of emulsion. Fine-grain emulsions have a greater surface-to-volume ratio than large-grain emulsions, and are, therefore, more vulnerable to the same level of residual thiosulfate. This explains why the archival print standard calls for lower residual thiosulfate levels than the LE100 film standard. Print emulsions have a much finer grain than film emulsions.

**Residual Thiosulfate Limits for Archival Processing of Photographic Film**

(in various units for LE500)

0.015 g/m$^2$
15.0 mg/m$^2$
0.15 mg/dm$^2$
0.0015 mg/cm$^2$
1.5 $\mu$g/cm$^2$

0.01 mg/in$^2$
10.0 $\mu$g/in$^2$

Film washing is a combination of displacement and diffusion. Initially, the wash water quickly displaces excess fixer by simply washing it off the surface. However, some thiosulfate will have been absorbed by the film emulsion, and it must diffuse into the surrounding wash water, before it can be washed away. As long as there is a difference in thiosulfate concentration between

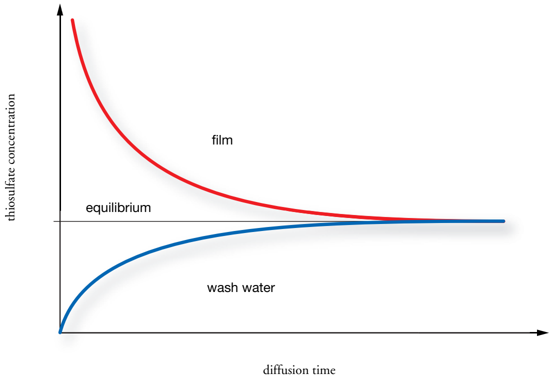


fig.11a As long as there is a difference in thiosulfate concentration between the film emulsion and the wash water, thiosulfate will diffuse from the film into the water. This gradually reduces the thiosulfate concentration in the film and increases it in the wash water. Diffusion continues until both are of the same concentration and an equilibrium is reached.

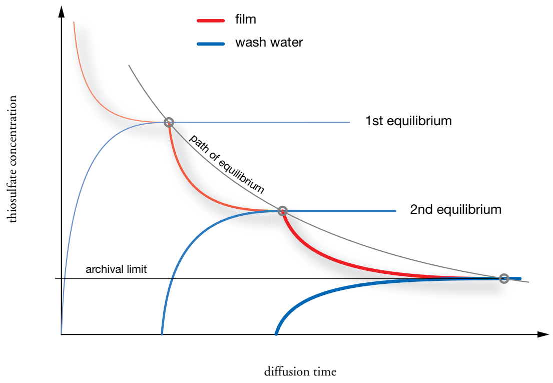


fig.11b During cascade washing, the saturated wash water is entirely replaced with fresh water each time the equilibrium is reached. This repeats the process of diffusion afresh. Cascade washing is continued until the residual thiosulfate level is at or below the archival processing limit.

the film emulsion and the wash water, thiosulfate will diffuse from the film into the water. The thiosulfate concentration gradually reduces in the film as it increases in the wash water (fig.11a). Diffusion continues until both are of the same concentration and an equilibrium is reached, at which point, no further diffusion takes place. Replacing the saturated wash water with fresh water restarts the process, and a new equilibrium at a lower thiosulfate level is obtained. The process is continued until the residual thiosulfate level is at, or below, the archival limit.

For quick and effective film washing, running water is recommended, because water replenishment over the entire paper surface is essential for even and thorough washing. A continuous supply of water also keeps the thiosulfate concentration different between film and wash water, and therefore, the rate of diffusion remains at a maximum during the entire wash. A standard wash in running water has the additional benefit of being very convenient. Once water flow and temperature are set, it needs little attention until done. However, in practice, this is a waste of water, and archival washing can also be achieved by a sequence of several complete changes of wash water, called cascade washing.

During cascade washing, the saturated wash water is entirely replaced with fresh water each time the equilibrium is reached. This repeats the process of diffusion afresh. Cascade washing is continued until the residual thiosulfate level is at or below the archival limit (fig.11b). The time to reach the diffusion equilibrium varies with film emulsion and depends on water temperature and agitation. The number of water replacements required to reach the archival residual thiosulfate limit depends on the volume of wash water used. Nevertheless, tests have shown that a typical roll film is easily washed to archival standards in 500 ml of water after 5-6 full exchanges, if left to diffuse for 5-6 minutes each time.

During a standard running-water wash, water-flow rates are kept relatively high. Typical literature recommendations are that the water flow must be sufficient to replace the entire water volume 4-6 times a minute. If preceded by a bath in washing-aid, archival washing is achieved after washing in running water for 10 minutes. Without the washing aid, a full 30-minute wash is required. A standard running-water wash is indeed a waste of water.

An effective film-washing alternative is a combination of a pure running-water wash and cascade washing. After the last fixing bath, fill the tank with water and immediately drain it to quickly wash excess fixer off the surface. Proceed with a 2-minute washing-aid bath before starting the actual wash. For hybrid washing, water-flow rates can be kept relatively low, since thiosulfate removal is limited by the rate of diffusion. Wash for 12 minutes, but completely drain the tank every 3 minutes during that time. Hybrid washing yields a film fully washed to archival standards and uses far less water than a pure running-water wash. Hybrid and cascade washing share the additional benefit of dislodging all wash-impeding air bubbles, which potentially form during the wash on the film emulsion, every time the water is drained.

Washing efficiency increases with water temperature, but a temperature between 20-25°C (68-77°F) is ideal. Higher washing temperatures soften the film emulsion and make it prone to handling damage. The wash water is best kept within 3°C of the film processing temperature to avoid reticulation, which is a distortion of the emulsion, caused by sudden changes in temperature. If you are unable to heat the wash water, prepare an intermediate water bath to provide a more gradual temperature change. If the water temperature falls below 20°C (68°F), increase the washing time and verify the washing efficiency through testing. Avoid washing temperatures below 10°C (50°F). Test show that washing efficiency is increased by water hardness. Soft water is not ideal for film washing.

## Testing for Permanence

Archival permanence and maximum life expectancy of a negative depend on the success of the fixing and washing processes. Successful fixing converts, all non-exposed but still light sensitive, silver halides and all silver complexes to soluble silver salts and washes most of them off the film. Successful washing removes the remaining silver salts from the emulsion and reduces the residual thiosulfate to safe archival levels. To verify an archival permanence, two tests are required: one to check for the presence of unwanted silver and one to measure the residual thiosulfate content.

### Testing Fixing Efficiency

Optimum fixing reduces the negative's non-image silver to archival levels of less than 0.016 g/m². Incomplete fixing, caused by either exhausted or old fixer, an insufficient fixing time or poor washing, is detectable by sulfide toning.

Apply a drop of working-strength sulfide toner to the still damp margin of the negative. Carefully blot the spot after 2 minutes. If too much non-image silver is still present, the toner reacts with the silver and creates brown silver sulfide. Any stain in excess of a barely visible pale cream indicates the presence of unwanted silver and, consequently, incomplete fixing or washing. Compare the test stain with a well-fixed material reference sample for a more objective judgment, and if required, refix the film in fresh fixer and wash it again thoroughly.

### Testing Washing Efficiency

Tests for residual thiosulfate can be applied either to the wash water or to the film emulsion itself. For increased accuracy, a test applied to the emulsion is preferred but complex and beyond the means of a regular darkroom setup. The Kodak HT2 hypo test works well for prints, because the color change of the test solution is easy to interpret on white paper, but it is impossible to read reliably on clear film. Sophisticated thiosulfate tests, such as the methylene-blue or the iodine-amylose test, are very accurate alternatives but are best left to professional labs.

The older Kodak HT1a hypo test is applied to the film's last wash water but is usually disregarded for accurate thiosulfate testing. However, if conducted with care, it can return sufficiently reliable results.

Immerse a fully washed film into a 0.5-liter bath of distilled water. With light agitation, let it soak for 6-10 minutes, after which, the residual thiosulfate is fully diffused and an equilibrium between film and wash water is reached. In other words, at that point, the thiosulfate concentration of the wash water is the same as that of the film emulsion.

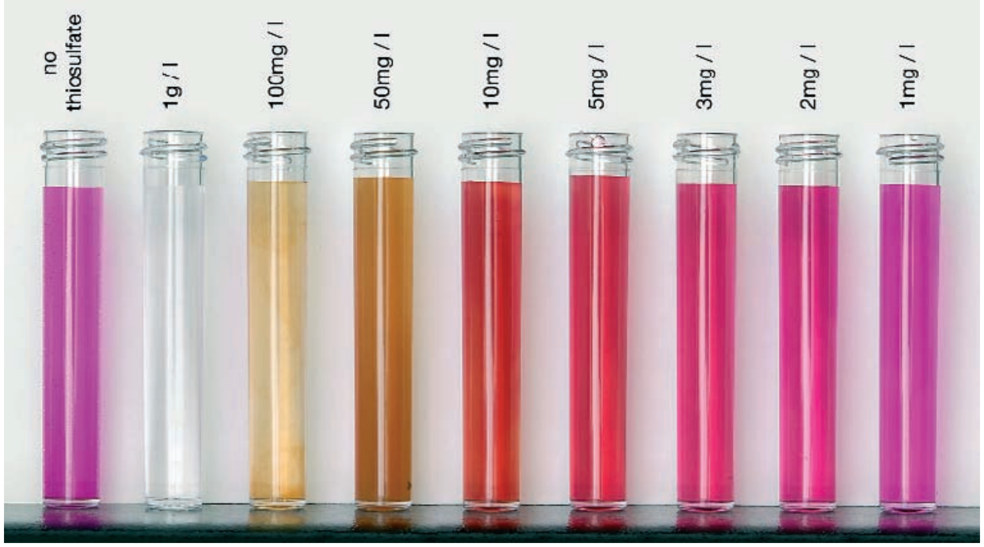


fig.12 Kodak's HT1a test solution is applied to the film's last wash water. The color of the test solution depends on its thiosulfate content and becomes a rough measure of the emulsion's residual thiosulfate level.

A typical 35mm or 120 roll film has a surface area of roughly 80 in² or 0.05 m². If it has been washed to the archival standard of 15 mg/m², and the residual thiosulfate of one roll film (0.75 mg) is fully diffused in 0.5 liter wash water, the thiosulfate concentration of the water must be at or below 1.5 mg/l.

Take two clean 10ml test tubes. Fill one with distilled water (master sample) and the other with the wash water to be tested (test sample). Add 1 ml (about 12 drops) of the HT1a solution to each test tube, swirl them lightly, and give the liquids a few seconds to mix and take on a homogeneous color. If there is no color difference between master and test sample, the film is fully washed and complies with the stringent LE500 requirement. The color samples in fig.12 are a rough measure of the actual thiosulfate content in the test sample, and theoretically, a slight red hue (< 5 mg/l) is permissible to comply with the LE100 standard for roll films. However, with this test, it does not hurt to err on the side of safety. After all, we are relying on the assumption that the residual thiosulfate has fully diffused into the wash water.

### Image Stabilization

The use of silver-image stabilizer after the wash is not recommended for films. To avoid staining, it must be thoroughly wiped off prints to remain only in the emulsion. But, intense and potentially abrasive wiping is harmful to the extremely sensitive film emulsion.

**Residual Thiosulfate Levels after Cascade Washing**

| Cascade | residual fixer |
|---|---|
| 1 | > 100 mg/l |
| 2 | 50 mg/l |
| 3 | 10 mg/l |
| 4 | 3 mg/l |
| 5 | 2 mg/l |
| 6 | 1 mg/l |

Kodak TMax-100, film-strength acid fixer
6-min soaks in 500 ml wash water
HT1a test results

Kodak
Photo-Flo 200 solution
CAT 146 4510

fig.13 A few drops of drying aid to the final rinse prevent unwanted water marks.

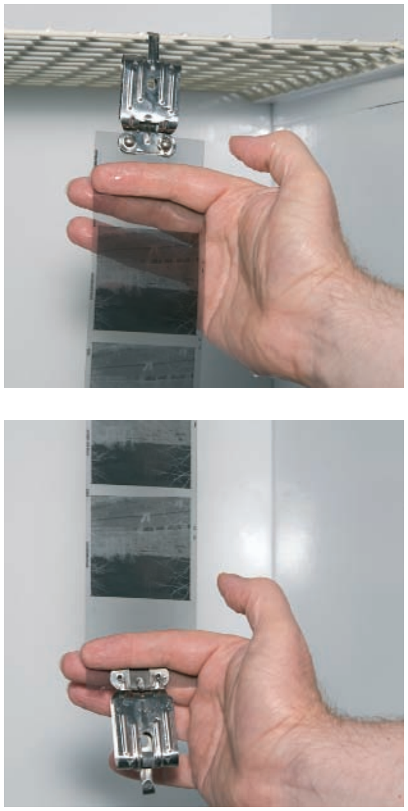


fig.14 To safely remove excess water, put your index and middle finger on either side at the top of the film, squeeze the fingers lightly together and carefully run them down the film once.

## Drying the Film

During this last film processing step, we must avoid three potential processing errors: water marks, mechanical damage and dust collection.

Water marks are calcium deposits caused by hard wash water and poor water drainage from the film. In many cases, this is prevented through a drying aid in the final rinse. Kodak's Photo-Flo 200 is such a product (fig.13). Start by adding a few drops to create a 1:1,000 solution. Depending on water hardness, increase to the recommended 1:200 solution, but too much wetting agent itself leaves drying marks. If you still experience water marks, consider a final bath in distilled or deionized water and add Photo-Flo to make a 1:2,000 solution. Adding up to 20% pure alcohol to the final bath will speed up the subsequent drying process. To remove dried water marks, bathe the film for 2 minutes in a regular stop bath, wash it again and select one of the drying-aid methods above.

After carefully removing the film from the final rinse, hang it up to dry and add a weight at the bottom to keep the film from rolling up. Remove excess water by putting your index and middle finger on either side at the top of the film, squeeze the fingers lightly together and carefully run them down the film once (fig.14). This method is better than any rubber squeegee, wiper, chamois leather, cellulose sponge or other contraptions proclaimed to be safe. All these devises eventually catch a hard particle of dirt, and you, unaware of the danger, will run it down the film, scratching and ruining valuable negatives.

At normal room temperature and relative humidity levels, film dries within a few hours. This method works perfectly in most cases. At very low relative humidity levels, the film's plastic substrate picks up an electrostatic charge and attracts dust. Hang up a few damp towels, or run a hot shower for a couple of minutes to reduce this effect. Other than that, the film is best left undisturbed. Any air movement will launch unwanted dust particles into the air. Resist the temptation to increase the air flow by using an electric fan. It will blow numerous little dust particles right at your film, where they become firmly lodged into the soft emulsion and remain forever. To speed up drying and eliminate dust as much as possible, use a professional film drying cabinet. It filters the incoming air, heats it up and gently blows it across the film's surface, drying the film in 20-30 minutes.

## After-Treatment to the Rescue

Sophisticated methods for exposure and development, together with the knowledge and experience when to apply which, are the best way to obtain the perfect negative. But, when things go wrong, and unfortunately things go wrong sometimes, we need some repair options. The common reasons for things to go wrong are simple enough. One might forget to set the lightmeter to the new film's sensitivity, and as a consequence, a whole roll of film is accidently over- or underexposed by several stops, leaving little hope to recover the faded moment. Or, one might read the wrong development time off a chart or select the wrong temperature, and the film is over- or underdeveloped beyond recognition. The list of potential errors is a mile long. I have made them all, and many of them, more than once.

Actually, some exposure and development errors are not as harmful to print quality as one might at first think. An overexposed film, for example, will produce a dense negative, which in turn may require awfully long exposure times in the darkroom, but even an overexposure of several stops has no diminishing effect on print quality, unless negative densities reach the extremes of the characteristic curve. Also, minor to modest over- and underdevelopment can be easily corrected by adjusting the paper contrast. Nevertheless, other exposure and development errors may result in an unacceptable negative, which cannot be used to produce a quality print. These errors include anything beyond slight underexposure, excessive overexposure and strong under- or overdevelopment. In these cases, the only recovery option is a chemical treatment of the negative, and depending on whether too little or too much density, the treatment is called either intensification or reduction.

Before we rush into a negative rescue mission, let's be totally clear that intensification and reduction are only desperate salvaging methods. As amazing as some results can be, they rarely turn a poor negative into a perfect one, but in many cases, they allow you to print an otherwise totally lost negative. Sometimes it's better to have a mediocre print than no print at all.

On the other hand, many negative intensification and reduction procedures depend on highly toxic chemicals, and consequently, their application is dangerous and must be questioned. No image is worth risking anyone's health for it. There are a few standard darkroom chemicals, however, which can also be useful as simple negative intensifiers or reducers. Nevertheless, always remember to use the necessary precautions when handling darkroom chemicals.

### Simple Intensifier

Regular selenium or direct-sulfide toning can be used as a mild proportional intensifier, and is useful for increasing highlight densities without significantly affecting shadow densities. The procedure is carried out with a fully processed negative under normal room lighting. Immerse the negative in the toner and maintain a gentle but constant agitation. The effect is quite subtle, raising the contrast of a correctly exposed but underdeveloped negative by about 1/2 a grade. A contrast increase of up to 1 grade is achieved by using stronger toning solutions and prolonged toning. Thoroughly wash and dry the toned negative as you would with normal processing.

A greater contrast increase, sufficient to enable a negative to be printed 1-2 grades lower, is achieved by first bleaching it and then toning it in regular sulfide toner. The procedure starts with the negative being intermittently agitated in a 10% solution of potassium ferricyanide until it is pale and ghostlike. This may take up to an hour, after which it is fully washed and immersed into the toner. Within 30 seconds, the negative redevelops into a dense, deep-brown image. This simple intensification is useful to rescue an unintentionally underdeveloped negative, but cannot reveal deep shadow detail in an underexposed frame.

### Simple Reducer

Farmer's Reducer is typically used to locally reduce print highlight densities, where it acts as 'liquid light' and gives print highlights the necessary brilliance. However, depending on dilution, it also works as a cutting and proportional reducer for overexposure and overdevelopment. Farmer's Reducer is a weak solution of potassium ferricyanide, mixed 1+1 with film-strength fixer just prior to use. Prepare a 2% potassium-ferricyanide solution as a cutting reducer and a 1% solution as a proportional reducer.

Under normal room lighting, immerse the fully processed negative in the solution and keep it constantly agitated. The reducer works imperceptibly at first, but as soon as the shadows lighten considerably, remove it and rinse it thoroughly. Afterwards, fix the negative in fresh fixer and continue with normal processing as shown in fig.1.

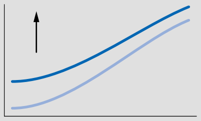
### Traditional After-Treatment

The first approach in working with a less than perfect negative is to adjust the paper contrast and optimize the print exposure. Toner intensification and Farmer's Reducer provide additional correction in some cases. Whenever stronger rescue missions are required, or a different effect is desired, one still has the option to reach for other, more toxic, chemicals.

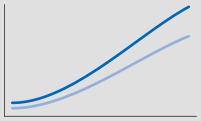
The hesitation to deal with additional and dangerous chemicals, combined with the possibilities gained through the invention of variable-contrast papers,

### Intensification

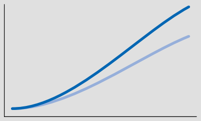
1. **Sub-proportional**
   Shadows are more intensified than highlights, which increases shadow detail, reduces contrast and makes up for some underexposure.



2. **Proportional**
   Shadow and highlight are intensified by a similar percentage, which increases contrast and compensates for underdevelopment.

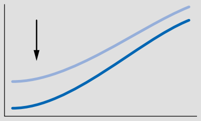


3. **Super-proportional**
   Highlights are more intensified than shadows, which increases highlight detail and contrast to useful levels for extreme low-contrast scenes.

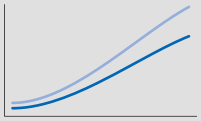


### Reduction

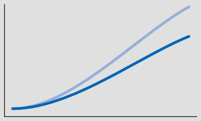
1. **Sub-proportional** *(cutting)*
   Shadows are more reduced than highlights, which increases contrast and cleans shadows, thereby correcting for overexposure.



2. **Proportional**
   Shadow and highlight are reduced by a similar percentage, which reduces contrast and compensates for overdevelopment.



3. **Super-proportional**
   Highlights are more reduced than shadows, which lowers extreme contrast, often found in high-contrast scenes, to more workable levels.



have demoted intensification and reduction from a standard after-treatment to an exceptional salvaging method. Consequently, they do not get the same literature coverage as they got decades ago. For example, 'The Manual of Photography', 5th edition, published in 1958, covers negative after-treatment in detail, but it no longer mentions it in the 9th edition, published in 2000. To include available formulae for negative intensification and reduction in this chapter is also beyond the scope of this book. However, Steve Anchell's *The Darkroom Cookbook* includes many formulae for people who can safely handle chemicals such as chromium and mercuric chloride, which is possibly the most toxic ingredient used in photography. Another detailed coverage of the subject is found in a four-part magazine article called 'Negative First Aid' by Liam Lawless, which was published in *Darkroom User* 1997, issues 3-6.

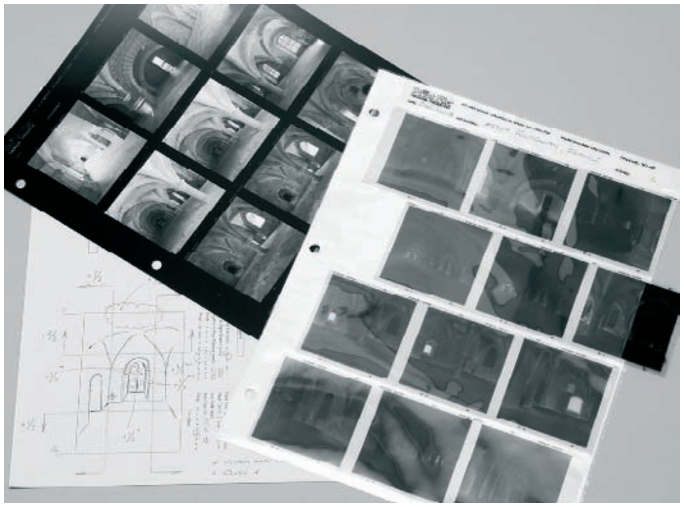


fig.15 Negatives are stored in oxidant- and acid-free sleeves, which are properly labeled for future reference. It is convenient to file copy sheets and printing records together with the negative sleeves.

## Negative Storage

Negatives usually have a good chance to survive the challenges of time, because they are often well protected, handled rarely and stored in the dark. However, common reasons for negatives to have a reduced life expectancy are sloppy film processing, ill handling, unnecessary exposure to light, extreme humidity, inappropriate storage materials and adverse environmental conditions. A summary of important film processing, handling and negative storage recommendations are in the text box below. These recommendations are not as strict as a museum or national archive would demand, but they are practical and robust enough to protect valuable negatives for a long time. Reasonable care will go a long way towards the longevity of photographic materials.

The main message I want you to take away from the last two chapters is that we use exposure to control the shadow densities of the negative, and we use development control to achieve the appropriate highlight densities. This balance between exposure and development control will create a negative that is easy to print, and it also promotes print manipulation from salvaging technique to creative freedom.

**Film Processing, Handling and Negative Storage Recommendations**

1. Film should only be processed in fresh chemicals. Without exception, it must be well fixed and thoroughly washed.
2. Minimize all film handling, and always protect dry negatives from the oils and acids found on bare hands by wearing clean cotton, nylon or latex gloves. Avoid speaking while leaning over unprotected negatives.
3. Store valuable negatives in light-tight containers, and oxidant and acid-free sleeves.
4. The storage or display environment must be free of oxidizing compounds and chemical fumes. Before redecorating a room, remove all negatives and store them safely elsewhere for at least 4-6 weeks, before they are brought back.
5. Store negatives at a stable temperature at or below 20°C (68°F) and at a relative humidity between 30-50%. Do not use attics (too hot) or basements (too damp) as a depository for photographic materials. Store negatives in the dark, minimize the exposure to bright light to the actual time of printing, and always protect them from direct exposure to daylight.

# Advanced Development

## Are one film and one developer enough?

It is prudent to evaluate the effect of developers and film processing variables on negative quality, to verify if one can sufficiently alter a film's characteristics to suit universal or specific applications. In previous chapters, we have only discussed changing the film development time to accommodate the subject brightness range. We have not explored the consequences to negative characteristics, other than contrast, or the creative opportunities obtained from changing the developer or processing technique. This is especially interesting when one considers the claims made for various old developers not knowing how they affect modern films. The subject is vast, and over the years, most photographic books have touched on the subject. Two Focal Press publications stand out, *Developing* by Jacobson & Jacobson and *The Film Developing Cookbook*, by Anchell & Troop. However, even these books do not compare the variation in speed, grain, resolution and sharpness obtainable from one film by changing the developer or processing technique.

In this chapter, we can only scratch the surface and compare the results obtainable with one film and one standard developer with the results obtained with two other commonly used developers. The findings presented here infer, but do not assure, that a similar trend will exist with other emulsions and developers.

A major driver to improve film and developer materials has been the need to extract maximum quality (fine grain and high speed, sharpness and resolution) from small negative formats for the purpose of high-magnification enlargements. These attributes are less critical at the lower magnifications required with medium and large film formats. Assuming that fine-art photographers will predominantly use medium-format or larger negative sizes, this study employs a 6x7 roll film camera with a lens of proven high contrast and resolution, loaded with a medium-speed film. In addition, a pictorial comparison is made with print enlargements made from highly magnified 35mm negatives to examine the grain and edge effects.

## Outline

The objective of the first part of this evaluation is to compare the effects on tonality, grain, speed, sharpness and resolution obtainable from one film and one developer (Ilford HP5 Plus and ID-11), by varying the agitation and dilution of the development process. HP5 and ID-11 are representative of standard materials and should be indicative of other standards, such as Kodak Tri-X and D-76. The second part of the evaluation compares the range of results obtained from this combination, by substituting ID-11 with Ilford Perceptol (Microdol-X) and Agfa Rodinal, as prime examples of fine-grain and high-acutance developers, at normal dilutions and with intermittent agitation. In each case, the development time was adjusted to ensure normal negative contrast (N).

### Parameter Setting

An initial evaluation at fixed developer dilution and agitation, with development temperature set to 18°C and 24°C, and the development time adjusted to give normal contrast, yielded indistinguishable negatives. A literature search confirmed the potential effects of dilution and agitation on tonality, grain, speed, sharpness and resolution, but there were few mentions of temperature related effects. As a result, only developer dilution and agitation were considered significant process variables that affect negative characteristics and the final print.

The required developer dilution is highly dependent upon the actual developer used. Agfa Rodinal, for example, has standard dilutions of 1+25 and 1+50 but can be used up to 1+200. ID-11 is typically used

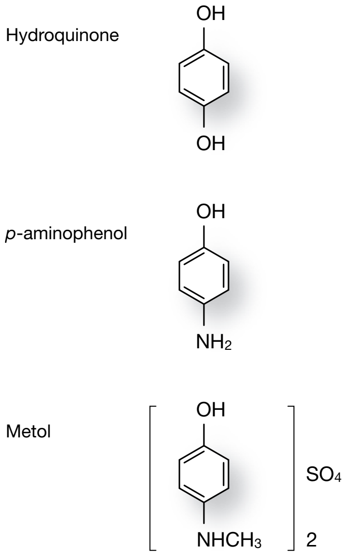


fig.1 Most active developing agents are based on benzine rings. The active ingredients shown here are represented in the three developers that are compared in this chapter. ID-11 (D-76) uses a combination of Metol and Hydroquinone, Rodinal uses para-aminophenol and Perceptol (Microdol-X) uses Metol alone.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50024-7

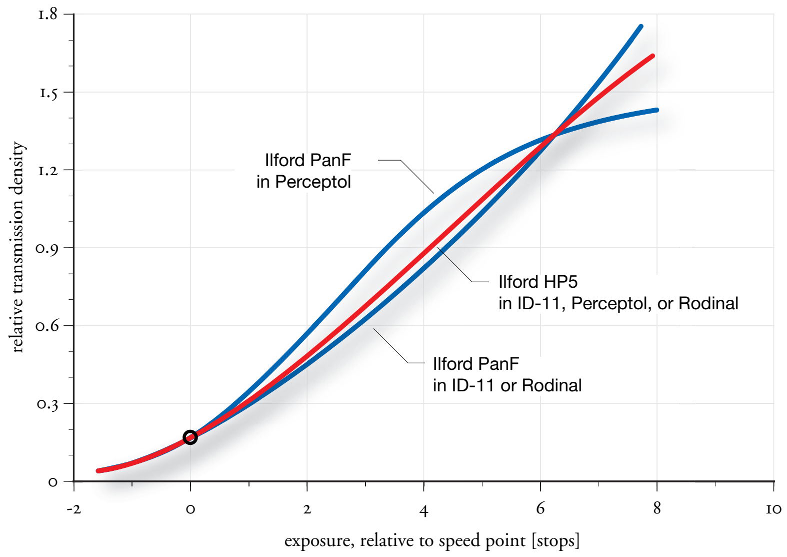


fig.2 A comparison of PanF and HP5 characteristic curves, developed in three different developers, demonstrates the uniqueness of certain combinations. HP5 characteristics are almost identical with all three developers, whereas PanF responds differently to one developer. This highlights the potential error of generalizing developer properties and reinforces the point that the only way to really understand material behavior is to test it.

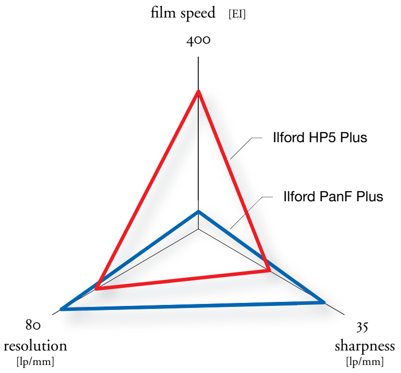


fig.3 Film selection is always a compromise between film speed, sharpness and resolution. No film can have it all!

undiluted, 1+1 and 1+3. At higher dilutions, there may be a lack of active developing agents in the solution to fully develop the film. This evaluation uses two dilutions (1+1 and 1+3) and the two extremes of agitation (continuous and stand), using a Jobo CPE-2 rotary processor and standard development tanks.

### Calibration

A serious exposure or development error can significantly change negative grain and resolution. A meaningful comparison mandates that negatives with identical effective exposure and contrast are made. Consequently, initial testing was required to establish a standard development time and the exposure index (EI) for each film, developer and all agitation and dilution combinations in question. For this, a Stouffer step tablet was photographed repeatedly to create a sufficient amount of test films. These films were subsequently processed, according to a test plan, which included all developers and developing schemes.

After drying, the films were evaluated, using the process laid out in the chapter 'Creating a Standard', and the speed points and gradients were measured. This employed the 'Film Average Gradient Meter' and 'Film Characteristic Curves' found in the 'Tables and Templates' section to establish the normal development time and the effective film exposure index for each variation. At this point, I was able to compare the relative exposure indexes for each combination.

### Pictorial Analysis

I also conducted a pictorial analysis to compare tonality, grain, sharpness and resolution, by using resolution and MTF targets and evaluating the pictorial impact on a detailed high-contrast scene. Using the predetermined EI and development times for each development scheme, eight films were exposed at the effective EI, carefully labeled, developed and their negatives enlarged to make prints.

For each film, the resolution values at which the MTF contrast fell to 50% and 10% of its peak were obtained, using the measurement methods established in the chapter 'Digital Capture Alternatives'. These give an objective indicator of acceptable sharpness and resolution, respectively. The prints give a pictorial presentation of grain and acutance. These are enlarged sufficiently to overcome the limitations of the book printing process and should be viewed at arm's length to mimic a more realistic reproduction ratio.

## Results

### Tonality

Some emulsion and developer combinations are known for their individual characteristics. In this particular instance, Ilford HP5 in Perceptol, Rodinal and the various ID-11 combinations give a consistent, almost straight-line characteristic curve with a slight toe and no shoulder. Fig.2 shows a typical characteristic curve for HP5 in any of these three developers. From previous experience, I know that ID-11 and Perceptol can behave very differently with other films. Fig.2 also compares the tonality of Ilford HP5 and PanF in ID-11, Rodinal and Perceptol. Clearly, there are hidden synergies with certain film and developer combinations, which can only be obtained with patient experimentation.

### Speed

An exposure index or speed variation of 2/3 stop was achieved by changing ID-11's concentration and the agitation scheme. The developers Rodinal and Perceptol create lower exposure indexes. High-dilution, stand development yielded the highest exposure index, and low-dilution, continuous-agitation development, created the lowest. In general, with one developer, the longer the development time, the higher the exposure index, for the same negative contrast.

### Sharpness and Resolution

As well as the stable tonality of HP5 in the three developers, resolution was largely unaffected by the various ID-11 development schemes or by changing the developer. The resolution measurements are statistically the same for all the combinations. In all cases, the resolution on medium-format film is sufficient for standard viewing conditions, and in most cases, better than required for critical viewing conditions.

A literature search suggests that high-dilution and low-agitation development enhance sharpness through image edge effects or acutance. Coarser details, measured at the 50% MTF point, showed the slightest increase in contrast for the dilute, low-agitation combination. Rodinal, known for its sharpness, fared no better than dilute ID-11 with stand development.

### Grain

A quantitative grain measurement is impractical for the amateur, but one can see and compare its effect and intrusion in enlargements. For this evaluation, a detailed high-contrast scene was photographed on 35mm HP5 with a particularly high-resolution, Carl Zeiss Distagon 2/35 ZF, lens on a Nikon F3. The scene was captured repeatedly at constant aperture and with bracketed exposure sequences. The film was cut into short sections and developed according to the predetermined schemes. Print enlargements with 20x magnification were made from equivalently exposed negatives (see fig.6), showing the pictorial impact of tonality, grain, sharpness and resolution.

The prints from negatives developed in ID-11 were virtually identical, apart from a slight improvement to fine tracery in the pylon and branches, a slightly lower local contrast between light and dark areas, and more even grain in the film developed with continuous agitation. There were no detectable edge effects in the continuous or stand-developed negatives. Prints made from negatives developed in Perceptol were similar, but they had slightly softer grain, which is in stark contrast to those developed in Rodinal.

Agfa's Rodinal, it's fair to say, is in a class of its own. With HP5, it produced negatives with character, giving detail to every faint twig, leaf and strut from the negative and adding an etched appearance to the image. The grain is very well defined and appears coarser than in the other prints. It is a classic case of a grain trade-off against increased visual sharpness.

### Are one film and one developer enough?

Over the years, I have used many film, developer and process combinations. Fueled with this experience and the claims of other publications, I approached this study with the expectation of a revelation. Even after numerous tests and calibrations, I scratched only the surface of this vast subject, yet found a significant outcome. It would appear that, since the days of Ansel Adams, the film companies have made their products more robust to processing variables.

Contrary to expectation, only subtle changes, unlikely to be visible at moderate enlargements, could be achieved by changing ID-11 dilution and agitation with HP5, mostly in apparent sharpness and film speed. Changing the developer had a more profound effect on speed, sharpness and grain. Tonality was unaffected, but as identified by prior observations with Ilford PanF, tonality is specific to a particular combination of developer and emulsion. While some developers, such as Rodinal, have a definite character that imposes itself on whatever it develops, many others are more middle-of-the-road developers. The inability to reliably predict the relative characteristics of most developer and emulsion combinations may well be the reason for the lack of such information in other publications.

Apparently, one film and one developer are not enough to meet all needs. One requires a few films, which cover a range of applications, as well as an all-purpose standard developer, such as D-76 or ID-11. The resulting combinations should be used with a consistent development process. For special applications, which require specific visual attributes, one should select an alternate developer, proven by experiment, to give the desired visual affect.

And yet, photographic chemistry rumors will most likely live on, despite scientific evaluation to the contrary. For instance, I decided to find out what was behind the miraculous claims attributed to prints made from stained negatives, which are created with Pyrogallol and Pyrocatechol developing agents in combination with Metol. These claims include improved grain, acutance and unmatched highlight separation. Although these developers have a reputation for being sensitive to aging, agitation, oxidation and streaking, they have a strong following and continuously draw interest with people who, for whatever reason, are not satisfied with established products. My

| | performance indicators | | | |
|---|---|---|---|---|
| developer dilution agitation | develop time [min] | (N) film speed [EI] | 10% MTF (resolution) [lp/mm] | 50% MTF (sharpness) [lp/mm] |
| ID-11 1+1 continuous | 10 | 320 | 56 | 17 |
| ID-11 1+3 continuous | 16 | 400 | 51 | 18 |
| ID-11 1+1 stand | 16 | 400 | 51 | 17 |
| ID-11 1+3 stand | 44 | 520 | 51 | 20 |
| Rodinal 1+100 inversion | 22 | 240 | 53 | 20 |
| Perceptol 1+3 inversion | 20 | 280 | 53 | 17 |

fig.4 This comparison shows that HP5 is very robust to different developers, dilutions and agitation techniques. The most obvious difference between development schemes is the effective film speed. Also, higher dilutions of ID-11 provide more sharpness (50% MTF), similar to the high-sharpness developer Rodinal. However, at print sizes of 16x20 or smaller, these differences are hardly recognizable with medium or large-format negatives. With 35mm film, on the other hand, resolution and sharpness differences become more obvious, due to the increased enlargement factor (see fig.6).

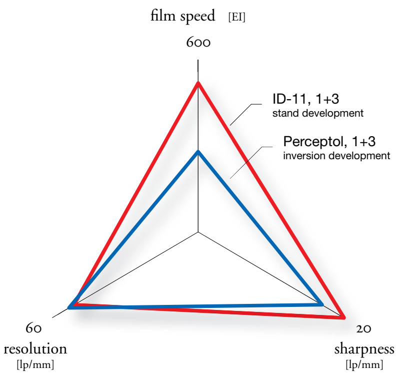


fig.5 A graphical presentation of the data in fig.4 illustrates the limitations of Ilford's HP5's response to different developers and developing techniques.

fig.6 These 20x enlargements of HP5 negatives indicate the extremes achieved with different developers, dilutions and agitation techniques. They show what I was unable to differentiate analytically. In fig.6a, ID-11 1+1 and continuous agitation brings out the fine details of the pylon and tree, but the lack of sharpness loses the visibility of some tracery. In fig.6b, ID-11 1+3 and stand development increases sharpness in fine details and local contrast but at the danger of obliterating the finest details with coarser grain. Some of the details look etched away. This trend is taken to extreme in fig.6c, where Rodinal and intermittent agitation accentuates the details in branches and pylon structure. Remarkably, this achieves a similar resolution as with ID-11 but with an obvious increase in grain. In fig.6d, Perceptol 1+3 and intermittent agitation produces the smoothest grain of all tested development schemes with otherwise similar properties to ID-11 1+1 with continuous agitation.

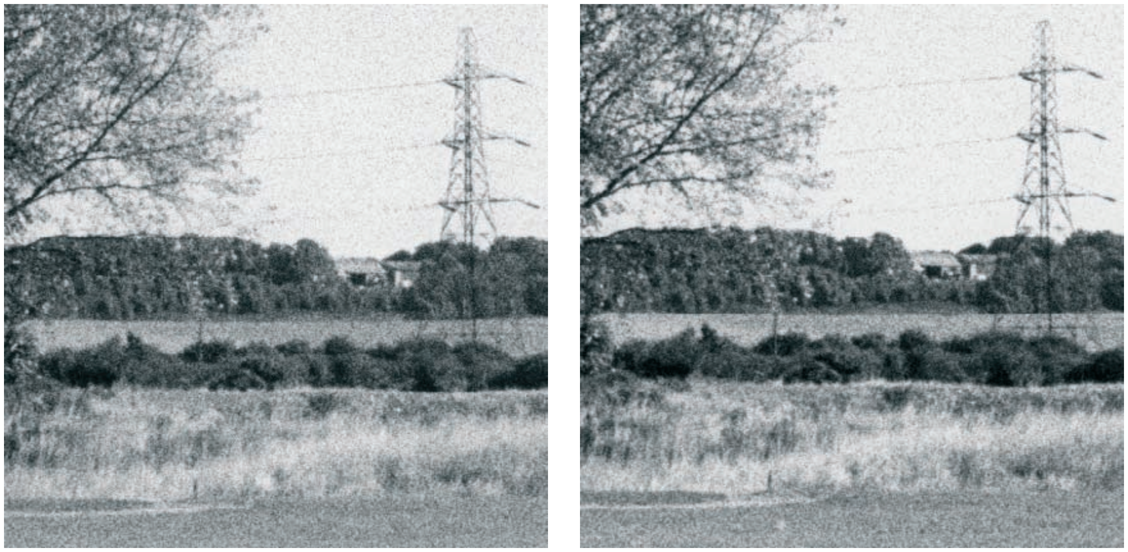


fig.6a ID-11, 1+1, continuous agitation

fig.6b ID-11, 1+3, stand agitation

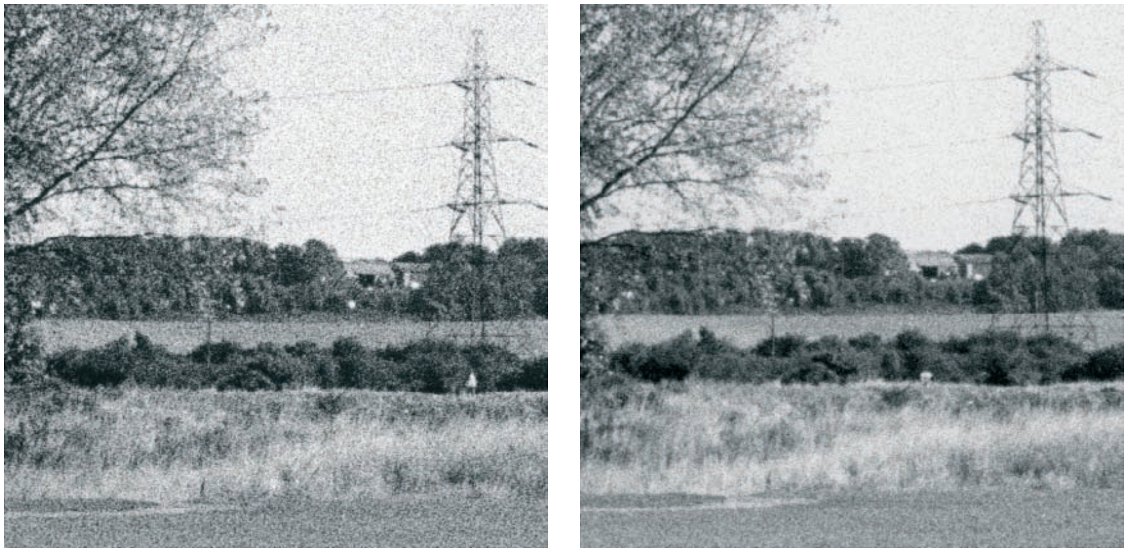


fig.6c Rodinal, 1+100, intermittent agitation

fig.6d Perceptol, 1+3, intermittent agitation

own sensitometry study and subjective comparison of three staining developers with a Metol-only developer (Perceptol) on HP5 produced four indistinguishable prints, despite these claims. In other words, at least in case of Ilford HP5 Plus, the claims are completely unjustified. Even so, the allure of the super-developer, solving all issues, remains undiminished, and it will take some time for some users to realize that the latest formula is just ‘another’ developer and not a magic recipe. It is important to realize that the robustness of an established developer, like Ilford’s ID-11, Kodak’s D-76 and Agfa’s Rodinal, which have been around for many decades, is often more important than fickle formulae with minor pictorial gain. Only adhering to robust darkroom processes and stabilizing one’s own technique, while establishing a thorough understanding of material behavior and responses, assures the results we all seek to be proud of.

# Creating a Standard

## Tone reproduction defines the boundaries and target values of the Zone System

A fine print can only come from a quality negative, and the Zone System is a fantastic tool to create such a perfect negative. Over the years, many Zone System practitioners have modified what they had been taught, adjusting the system to fit their own needs and work habits. This flexibility for customization has left some photographers with the perception that there are many different Zone Systems. That is not the case, but different interpretations and definitions of some key target values and boundary conditions do indeed exist. It is, therefore, beneficial for the rest of the book and the reader's understanding to create a 'standard' for some of the exposure and development assumptions, when using the Zone System. This will help to create a consistent message, eliminate confusion and build a solid foundation for your own customization in the future.

### Reading Shadows and Highlights

Expose for the shadows. This means that you have to select a shadow area, read the reflected light value with your spotmeter and then place it onto the appropriate zone to determine the exposure. This process is very subjective, because the appropriate zone is found through visualization alone. You find photographers using any one of Zone II, III or IV as a base for the shadow reading. Ansel Adams suggested Zone III, due to the fact that it still has textured shadows with important detail. Zone III creates a fairly obvious boundary between the fully textured details of Zone IV and the mere shadow tonality of Zone II. My experience shows that Zone IV is often selected with less confidence and consistency, and Zone II reflects only about 2% light, making accurate readings challenging for some equipment. Consequently, we will standardize on Zone III as the basis to determine shadow exposure.

Develop for the highlights. This means that you have to select a highlight area, read the reflected light value with your spotmeter and determine what zone it 'fell' onto. If that is not the visualized zone, then development correction is required to get it there. To

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50025-9

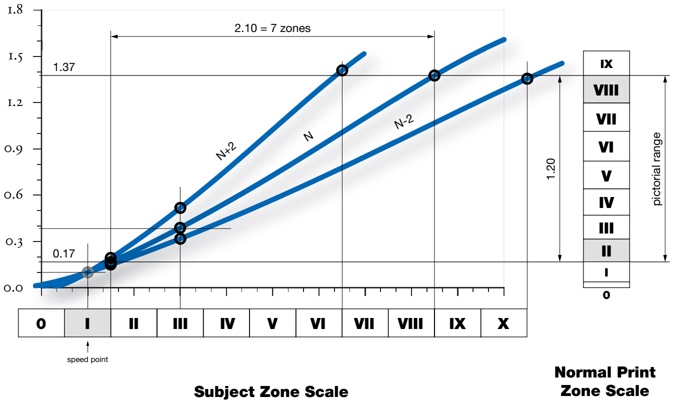


fig.1a Setting the speed point at Zone I allows for some fluctuations in low shadows (Zone I·5), and N-2 development leads to slightly weak shadow densities.

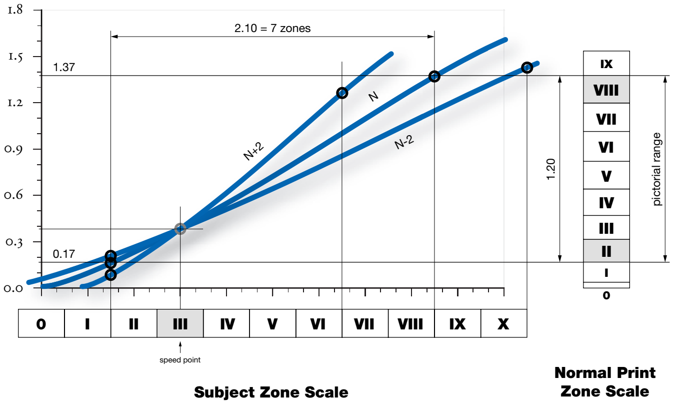


fig.1b With the speed point at Zone III, low shadow densities are inconsistent and far too weak with N+2 development. Highlights fluctuate by about one paper zone.

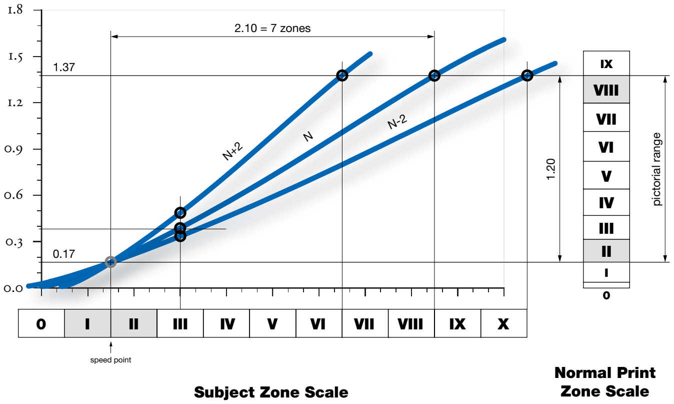


fig.1c Setting the speed point at Zone I·5 secures consistent densities for shadow and highlight tones regardless of development compensation. It is best to always place the speed point at the shadow anchor of the Zone System.

standardize on this zone for highlights is not simple, because it depends entirely on the subject. It could be a Zone V in a low-key image and it could be a Zone XI in the highlights of a snow filled scene. However, most of these situations are special cases, and we can safely assume that we will standardize on a scene with a complete tonal range from black to white. Ansel Adams suggested Zone VII, due to the fact that it still has textured highlights with important detail. Many beginners are surprised how 'dark' Zone VII is, and it seems to be far easier to visualize a Zone VIII, where we still find the brightest important highlights, before they quickly disappear into the last faint signs of tonality and then into paper white. We will standardize on Zone VIII as a basis to determine film development.

## Practical Boundaries

We have to remind ourselves that, in analog photography, the print is the only means of communication with the viewer of our photographs. Therefore, negative density boundaries have to support, and are limited by, the paper density boundaries. They have been defined in 'Tone Reproduction' and will be covered further in 'Fine-Tuning Print Exposure and Contrast'. We know from both chapters that modern printing papers are capable of representing 7 zones under normal lighting conditions. We will standardize on a normal subject brightness range to have 7 zones from the beginning of Zone II to the end of Zone VIII with relative log transmission densities of 0.17 and 1.37, respectively. These values assume the use of a diffusion enlarger and need adjustment if a condenser enlarger is used. Consequently, our standard negative density range is 1.20.

The log exposure range of grade-2 paper is limited to 1.05, but this ignores extreme low and high reflection densities. We have no problem fitting a negative density range of 1.20 onto grade-2 paper, if we allow the low end of Zone II and the high end of VIII to occupy these paper extremes. Our standard paper contrast is ISO grade 2.

A simple definition for compensating development is also required. Despite some existing textbooks with rather complicated definitions, we will use a very simple but useful interpretation. As stated above, normal development (N) will capture 7 zones (2.10 log exposure) within the fixed negative density range. N-1 will capture one zone more with reduced development, and N+1 will capture one zone less with increased development. A complete list can be seen in the bottom half of fig.2.

## Speed Point

We saw in the chapter 'Development and Film Processing' how the development time changes the average gradient and how it allows us to compensate for different lighting situations. Shorter development captures more subject brightness zones in a fixed negative density range, and longer development has the opposite effect. Of course, we are doing so to keep almost all maximum negative density at a fixed level, allowing all lighting scenarios to be printed on grade 2 paper. This leaves us with maximum paper contrast control and creative flexibility. In a dull low-contrast scene, the contrast is increased, and in a high-contrast scene, the contrast is reduced. In the dull scene, Zone VI might be the brightest subject 'highlight', and the increased contrast will lift it to a density level typically reserved for Zone VIII. In a high-contrast scene, Zone X might be reduced to a Zone VIII density, to keep it from burning-out in the print.

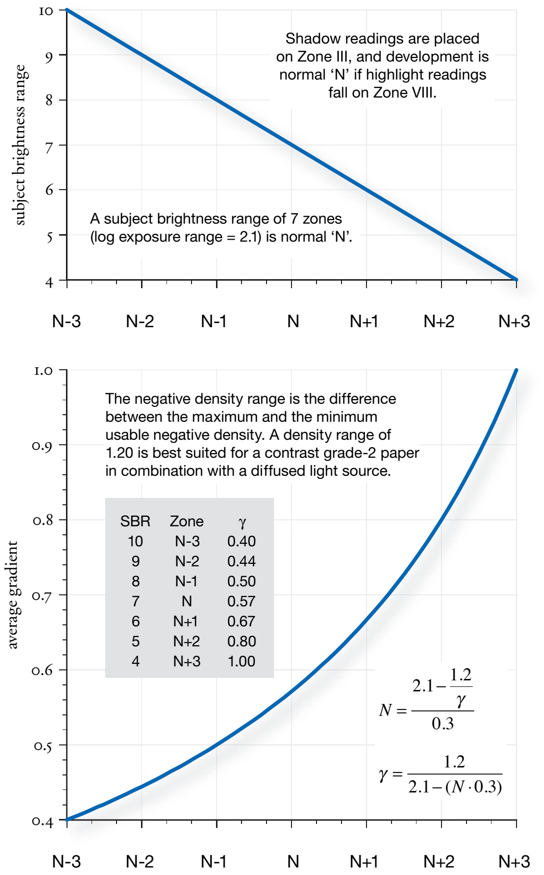
The entire negative zone scale is affected when highlight density is controlled by development. The individual zone densities 'move' within their proportional relationship. However, we can select one common point for all development curves by controlling the film exposure. They will all intersect at this point, and all curves will have the same negative density for a specific subject zone. This point is called the 'speed point', because it is controlled by the film exposure in general and the film speed in particular. It is also often referred to as the 'foot speed', because it is most likely found near the toe of the characteristic curve, where exposure has more influence on negative density than development time.

It is up to us where to set the speed point on the subject zone scale, but some locations are better than others. Fig.1 illustrates some possible locations. In fig.1a, the speed point is located at Zone I. This is a popular choice, but it allows for some density fluctuations in low shadows around Zone I·5, and N-2 development leads to slightly weak shadow densities. Highlight densities are fairly consistent and the density variations for Zone III are of little concern. In fig.1b, the speed point is located at Zone III. This seems to be an obvious choice at first, because it secures consistent Zone III densities. However, the low shadow densities are highly inconsistent and far too weak with N+2 development. The highlight densities fluctuate by about one paper zone. In fig.1c, the speed point is located at Zone I·5. This secures consistent densities for shadow and highlight tones regardless of development compensation. The textural density variations for Zone III are less than 1/3 stop, which is unavoidable and of no concern. It is best to always place the speed point at the shadow anchor of the Zone System. For us this means that our standard speed point is at Zone I·5 and has a negative density of 0.17.

## Average Gradient

The relationship between subject brightness range and average gradient in the Zone System can be taken from the two graphs in fig.2. This relationship is fixed to the Zone System development-compensations values if our standard values are assumed. In the subject-brightness-range graph (top), the normal scene is assumed to have a 7-stop difference between shadows and highlights. The average-gradient graph (bottom) is based on a fixed negative density range of 1.20. This negative density range assumes the use of a diffusion enlarger and an ISO grade-2 paper contrast as a desirable aim. You may want to lower the average gradient if you are working with a condenser enlarger. Their optics make a negative seem to be about a grade harder, but print with the same quality once the negative density range is adjusted. Use a negative density range of 0.90 as a starting point for your own evaluations. You may also want to make other adjustments to target average gradient values if you have severe lens and camera flare, or if you experience extremely low flare. The nomograph in 'Customizing Film Speed and Development' will help with any necessary adjustments.

We now have standard Zone System boundaries and target values. They can be used as a guide or as a rule, and they work well in practical photography. More importantly, we are using them throughout the book to be consistent.



Shadow readings are placed on Zone III, and development is normal 'N' if highlight readings fall on Zone VIII.

A subject brightness range of 7 zones (log exposure range = 2.1) is normal 'N'.

The negative density range is the difference between the maximum and the minimum usable negative density. A density range of 1.20 is best suited for a contrast grade-2 paper in combination with a diffused light source.

| SBR | Zone | γ |
|---|---|---|
| 10 | N-3 | 0.40 |
| 9 | N-2 | 0.44 |
| 8 | N-1 | 0.50 |
| 7 | N | 0.57 |
| 6 | N+1 | 0.67 |
| 5 | N+2 | 0.80 |
| 4 | N+3 | 1.00 |

$$N = \frac{2.1 - \frac{1.2}{\gamma}}{0.3}$$

$$\gamma = \frac{1.2}{2.1 - (N \cdot 0.3)}$$

fig.2 Subject brightness range (SBR) and average gradient (γ) have a fixed relationship to the Zone System development compensations when a few assumptions are made. In the subject-brightness-range graph (top), the normal scene is assumed to have a 7-stop difference between shadows and highlights. The average-gradient graph (bottom) is based on a fixed negative density range.

# Customizing Film Speed and Development

## Take control and make the Zone System work for you

Film manufacturers have spent a lot of time and resources establishing the film speed and the development time suggestions for their products. Not knowing the exact combination of products we use for our photographic intent, they have had to make a few assumptions. These assumptions have led to an agreement among film manufacturers, which were published as a standard in ASA PH2.5-1960. It was the first standard to gain worldwide acceptance, but it went through several revisions and was eventually replaced by the current standard ISO 6:1993, which combines the old ASA geometric sequence (50, 64, 80, 100, 125, 160, 200, ...) with the old DIN log sequence (18, 19, 20, 21, 22, 23, 24, ...). As an example, an ISO speed is written as ISO 100/21°.

Fig.2 shows a brief overview of the ISO standard. According to the standard, the film is exposed and processed so that a given log exposure of 1.30 has developed to a transmission density of 0.80, resulting in an average negative gradient of about 0.615. Then, the film speed is determined by the exposure, which is developed to a shadow density of 0.10. This makes it an acceptable standard for general photography. However, the standard's assumptions may not be valid for every photographic subject matter, and advertised film speeds and development times can only be used as starting points.

A fine-art photographer appreciates fine shadow detail and often has to deal with subject brightness ranges that are significantly smaller or greater than the normal 7 stops from the beginning of Zone II to the end of Zone VIII. In addition, the use of certain equipment, like the type of enlarger or the amount of lens flare, influences the appropriate average gradient and final film speed. The nomograph in fig.14 gives an overview of these variables and their influence. The Zone System is designed to control all these variables through

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50026-0

the proper exposure and development of the film. This requires adjustment of the manufacturer's film speed (or 'box speed') and development suggestions.

In general, advertised ISO film speeds are too optimistic and suggested development times are too long. It is more appropriate to establish an 'effective film speed' and a customized development time, which are personalized to the photographer's materials and technique. In most literature, the effective film speed is referred to as the exposure index (EI). Exposure index was a term used in older versions of the standard to describe a safety factor, but it was dropped with the standard update of 1960. Nevertheless, the term 'EI' is widely used when referring to the effective film speed, and we will accept the convention.

Still, we ask ourselves: How does one establish the effective film speed and development time to compensate for different subject brightness ranges? An organized test sequence can give you very accurate results, but even a few basic guidelines can make a big difference in picture quality. I would like to show you three different ways, with increasing amount of effort, to keep you from wasting your time on too many 'trial and error' methods.

## 1. Quick and Easy

Here is a simple technique, which will improve picture quality significantly and does not require any testing at all. Use it if you dislike testing with a passion, or if you just don't have the time for a test at the moment. This method can also be used to give a new film a test drive and compare it to the one you are using now.

For a normal contrast, bright but cloudy day, cut the manufacturer's recommended film speed by 2/3 stop (i.e. ISO 400/27° becomes ISO 250/25°) and the recommended development time by 15%. The increased exposure will boost the shadow detail, and the reduced development time will prevent the highlights from becoming too dense. For a high-contrast, bright and sunny day, increase the exposure by an additional 2/3 stop (i.e., ISO 400/27° now becomes ISO 160/23°) and reduce the development time by a total of 30%. Stick to the 'box speed' and suggested development time for images taken on a low-contrast, rainy or foggy day.

A negative processed this way will easily print with a diffusion enlarger on grade-2 or 2.5 papers. Just give it a try (fig.1). It is really that simple to make a significant improvement to negative and image quality.

## 2. Fast and Practical

Here is another way to arrive at your effective film speed and customized development time. It is a very practical approach, which considers the entire image producing process from film exposure to the final print. The results are more accurate than from the previous method, and it requires three simple tests, but no special equipment.

### a. Paper-Black Density Test

This test will define the minimum print exposure required to produce a near-maximum paper density. Make sure to use a blank negative from a fully processed film of the same brand as to be tested. Add a scratch or a mark to it, and use it later as a focus aid.

1. Insert the blank negative into the negative carrier.
2. Set the enlarger height to project a full-frame 8x10 inch print and insert contrast filter 2 or equivalent.
3. Focus accurately, then measure and record the distance from the easel to the film.
4. Stop the lens down by 3 stops and record the f/stop.
5. Prepare a test strip with 8, 10, 13, 16, 20, 25 and 32-second exposures.
6. Process and dry normally.
7. In normal room light, make sure that you have at least two but not more than five exposures, which

| scene contrast | adjustments | | typical subject brightness range |
|---|---|---|---|
| | film speed [ASA] | development time | |
| low | - | - | rainy or foggy day |
| normal | -2/3 | - 15% | bright but cloudy day |
| high | -1 1/3 | - 30% | bright sunny day |

fig.1 It is possible to make significant improvements to negative and image quality without any testing. Use this table to deviate from the manufacture's recommendations for film exposure and development according to overall scene contrast.

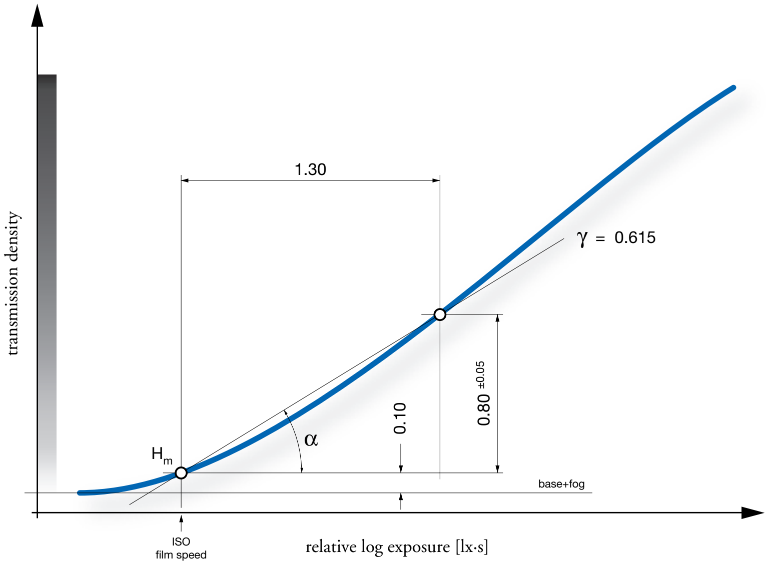


fig.2 Film exposure and development in accordance with the current ISO standard.

are so dark that they barely differ from one another. Otherwise, go back to step (5) and make the necessary exposure corrections.

8. Pick out the first two steps that barely differ from one another and select the lighter of the two.
9. Record the exposure time for this step.

This is the exposure time required to reach a near-maximum paper density (Zone 0) for this aperture and magnification. If you can, leave the setup in place as it is, but record the f/stop, enlarger height and exposure time for future reference.

### b. Effective Film Speed Test

This test will define your normal effective film speed, based on proper shadow exposure.

1. Select a subject, which is rich in detailed shadows (Zone III) and has some shadow tonality (Zone II).
2. Set your lightmeter to the advertised film speed.
3. Stop the lens down 4 stops from wide open, and determine the exposure time for this aperture, either with an incident meter pointing to the camera, or place a 'Kodak Gray Card' into the scene, and take the reading with a spotmeter. Keep the exposure time within 1/8 and 1/250 of a second or modify the aperture.
4. Make the first exposure.
5. Open the lens aperture or change the ISO setting of your lightmeter to increase the exposure by 1/3 stop (i.e., ISO 400/27° becomes ISO 320/26°) and make another exposure. Record the exposure setting.
6. Repeat step (5) four times, and then, fill the roll with the setting from step (4).
7. Develop the film for 15% less time than recommended by the manufacturer. Otherwise, process and dry the film normally.
8. Set your enlarger and timer to the recorded settings for the already determined Zone-0 exposure from the previous test.
9. Print the first five frames, process and dry normally.

An evaluation of the prints will reveal how the shadow detail is improving rapidly with increased film exposure. However, there will come a point where increased exposure offers little further benefit. Select the first print with good shadow detail. The film speed used to expose the related negative is your normal effective film speed for this film. Based on my experience, it is normal for the effective film speed to be up to a stop slower than the rated film speed.

Fig.3a-c show just how much difference the effective film speed can make. Fig.3a is the result of a negative exposed at ISO 125/22° and then printed with the minimum exposure time required to get a Zone-0 film rebate with a grade-2 paper. The highlights are 'dirty', the midtones are too dark and 'muddy', and the shadows are 'dead' with little or no detail. In fig.3b, an attempt was made to produce a 'best print' from the same negative. The film rebate was ignored, the exposure was corrected for the highlights, and contrast was raised to optimize shadow appearance. The highlights and midtones are much improved, but the gray card is still a bit dark. The shadows are solid black, still without any detail, and the picture has an overall harsh look to it. Fig.3c is the result of a negative exposed at an effective film speed of EI 80, and then printed in the same way as fig.3a. The highlights are bright, but not as harsh as in fig.3b, the gray card is on Zone V as intended, and the shadows are deep black with detail. A big improvement, solely due to selecting the effective film speed.

### c. Film Developing Time Test

This test will define your normal film development time. A rule of thumb will be used to adjust the normal development time to actual lighting condition, where needed.

1. Take two rolls of film. Load one into the camera. On a cloudy but bright day, find a scene that has both significant shadow and highlight detail. A house with dark shrubs in the front yard and a white garage door is ideal.
2. Secure your camera on a tripod, and set your lightmeter to your effective film speed, determined by the previous test. Meter the shadow detail, and place it on Zone III by reducing the measured exposure by 2 stops.
3. At that setting, shoot the scene repeatedly until you have finished both rolls of film.
4. In the darkroom cut both rolls in half. Develop one half roll at the manufacturer's recommended time. Develop another half roll at the above time minus 15% and another half roll at minus 30%. Save the final half roll for fine-tuning.

5. When the film is dry, make an 8x10-inch print from one negative of each piece of film at the Zone-0 exposure setting, determined during the first test. The developing time used to create the negative, producing the best highlight detail, is your normal film developing time. You may need the fourth half roll to fine-tune the development.

Considering your entire image-making equipment, you have now determined your effective film speed, producing optimum shadow detail, and your customized film developing time, producing the best printable highlight detail for normal lighting conditions.

However, film exposure and development have to be modified if lighting conditions deviate from 'normal'. The rule of thumb is to increase the exposure by 1/3 stop whenever the subject brightness range is increased by one zone (N-1), while also decreasing development time by 15%. On the other hand, decrease the exposure by 1/3 stop whenever the subject brightness range is decreased by one zone (N+1), while increasing development time by 25%.

These tests must be conducted for every combination of film and developer you intend to use. Fortunately, this is not a lot of work and will make a world of difference in your photography.

## 3. Elaborate and Precise

The following method of determining the effective film speed and development time is more involved than the previous two, and it requires the help of a densitometer to read negative transmission densities accurately. The benefit, however, is that it supplies us will all the information we need within one test. It gives enough data to get the effective film speed and how it changes with different development times. We will also get an accurate development time for every possible subject brightness range. Negatives exposed and developed with this information should have a constant and predictable negative density range for any lighting situation. This method is ideally suited for use with the Zone System. The final results are well worth the time commitment of about 8 hours to perform the test and to evaluate the data.

The use of a densitometer is essential for this test. A densitometer is costly and, therefore, typically a rare piece of equipment in regular darkrooms. A quality densitometer costs as much as a 35mm SLR, if purchased new, but they are often available for a fraction of that on the used market. This test only requires us to read transmission densities, but a densitometer which is able to read both transmission and reflection is a much more versatile piece of equipment. Some darkroom analyzers have a built-in densitometer

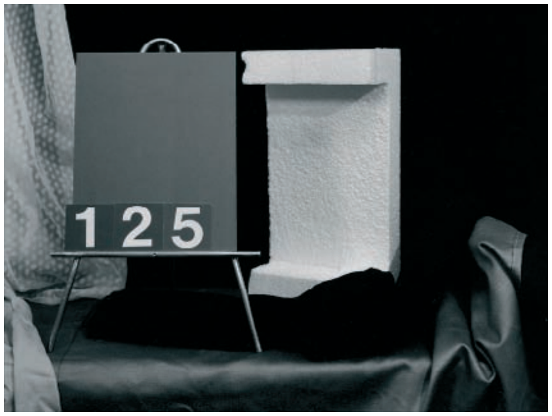


fig.3a The negative was exposed at ISO 125/22° and then printed with the minimum exposure time required to get a Zone-0 film rebate with a grade-2 paper. This results in 'dirty' highlights, 'muddy' midtones and 'dead' shadows.

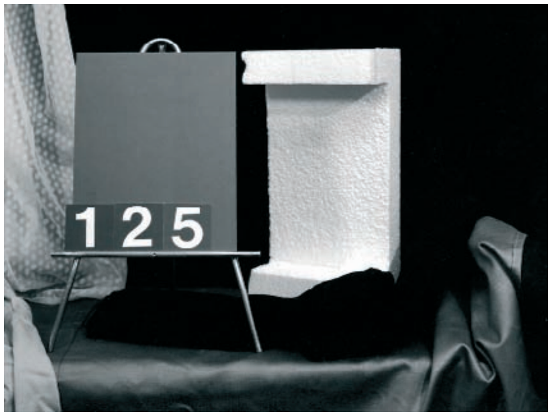


fig.3b ISO 125/22°. Print exposure and contrast were changed to make 'best print'. Highlights and midtones are improved, but there is still no shadow detail.

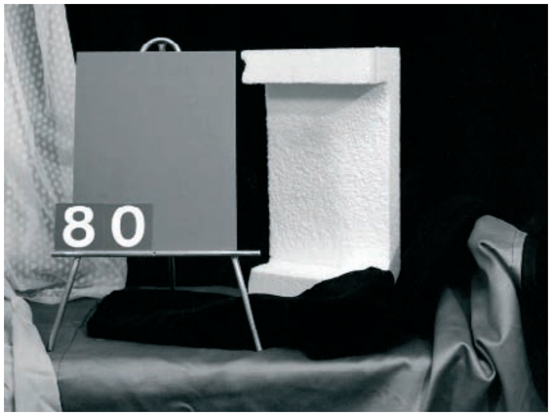


fig.3c EI 80/18°. A film exposure increase but a print exposure as in fig.3a results in bright highlights similar to fig.3b, with improved mid-tone and shadow detail.

(test & images by Bernard Turnbull)

function, and they can be used to read projected negative densities. Alternatively, you may ask a friend or the local photo lab to read the densities for you. Once you have a densitometer, you will find many uses for it around your darkroom.

### Exposure

Many different methods of generating the necessary negative test exposures have been published. Most require changes to lens aperture or camera shutter settings for exposure control. If conducted with care, this is a very practical method providing acceptable accuracy. However, years of testing have made me aware of some equipment limitations, which we need to take into consideration to get reliable results.

Mechanical shutters are rarely within 1/3-stop accuracy, and their performance is very temperature sensitive, acting slower when cold. They also become sluggish after long periods of non-use. In these cases, it helps to work the shutter by triggering the mechanism a few times. In any event, they cannot be set in fine increments, and exposure deviations should be recorded down to 1/3 stop. This is not possible with mechanical shutters. Electronic shutters, on the other hand, are very precise, and sometimes provide 1/3-stop increments, although they are uncommon in large-format equipment. Lens aperture accuracy is usually very good, being within 1/10 stop, but apertures are notorious for being off at the largest and smallest setting. Medium aperture settings are far more trustworthy, but only if worked in one direction. Switching from f/8 to f/11 may not result in the same aperture as switching from f/16 to f/11, due to what is known as mechanical hysteresis. Consequently, we can use shutters and lens apertures to control test exposures, but must avoid mechanical shutters and change f/stops only in one direction.

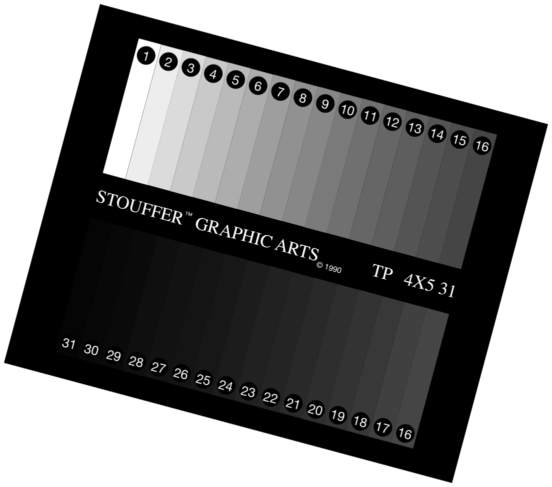


fig.4 The Stouffer 31-step tablet

As an alternative, consider the use of a step tablet wherever possible. A step tablet is a very accurate and repeatable way to expose a piece of film. Fig.4 shows one supplied by Stouffer in Indiana, but they are available from different manufactures and in different sizes. The process is most simple if you purchase one in the same size as the negative format to be tested, and photograph it with the aid of a slide duplicator. If such a device is not available, then a similar setup can easily be rigged up. It can be as simple as placing the step tablet onto a light table, and taking a close-up copy.

I prefer the 31-step tablet to the 21-step version, due to the higher quantity of data points available. However, in the process of copying the step tablet, be certain that the steps on the final negative are wider than the measuring cell of the densitometer, otherwise you will not be able to read the density values properly. This may necessitate opting for the 21-step version with its wider bars or adjusting the scaling when you photograph the step tablet. This will be most likely the case only with 35mm negatives. You should be able to fit the 31-step version with most medium format and 4x5-inch film.

Film has a different sensitivity to different wavelengths of light. Therefore, select a light source with a color temperature representative of your typical subject matter and setup. In other words, use daylight or daylight bulbs if you are a landscape photographer, and use photofloods or flashlight if you mainly work in the studio. However, always keep exposure times between 1/500 s and 1/2 s to avoid reciprocity failure.

Assume the box speed to be correct and determine the right exposure with an average reading, or use a spotmeter for the medium gray bars. You can use the manufacturer's recommended film speed, since the actual exposure is not critical as long as it is within 1 stop. The worst that can happen is that a few bars are lost on either end. Once the step tablet is photographed and developed, you will have 21 or 31 accurately spaced exposures on every frame. They are accurate, because their relative exposure is fixed through the densities of the step tablet, and are not affected by any shutter speed or lens aperture inaccuracies. If you are testing sheet film, expose five sheets with the same exposure. If you are testing roll film, fill five rolls of film with the same exposure on every frame.

### Development

Select the developer, its dilution and temperature you intend to use for this film. Develop the film in the same manner as you would normally, but for fixed and closely controlled development times. Develop the first roll or sheet for 4 minutes, the next for 5.5 minutes and the following for 8, 11 and 16 minutes, respectively.

Start timing after the developer has been poured into the developing tank, and stop timing after it has been poured out again. Process and dry all film normally.

Make sure that all processing variables are constant and the only difference between these films is the development time. The temperature of the developer is critical, but it is more important to have a consistent temperature than an accurate one. Try to maintain an almost constant developer temperature throughout the process. Keeping the developing tank in a tempered water bath will help to do so. It does not matter if your thermometer is off by a degree or two as long as it reads the same temperature for the same amount of heat all the time. Do not switch thermometers. Pick one, and stick to it for all of your darkroom calibrations. For this test, all chemicals should be used as one-shot, but most importantly, do not reuse any developer solution. It does exhaust with use, and these five films must be developed consistently. The other chemicals are not as critical, but I still suggest using fresh chemicals for film development.

In addition, watch the film/developer ratio. The active ingredients of the developer are gradually exhausted during development. The rate of exhaustion during the test must be similar to your typical application. For example, do not develop one 4x5 test sheet in 1.5 liters of developer if you normally process six at a time in the same volume. Six sheets of film will exhaust the developer more quickly than just one, and consequently, negative densities of the test film will be higher than from normal development. In this case, prepare additional test sheets, also exposed with the step tablet, and develop them together with the actual test film.

Always conduct the test with film in your favored format. Emulsion thicknesses differ between film formats, and consequently, so does the development time. A test based on one film format may not be valid for another.

### Collecting and Charting the Data

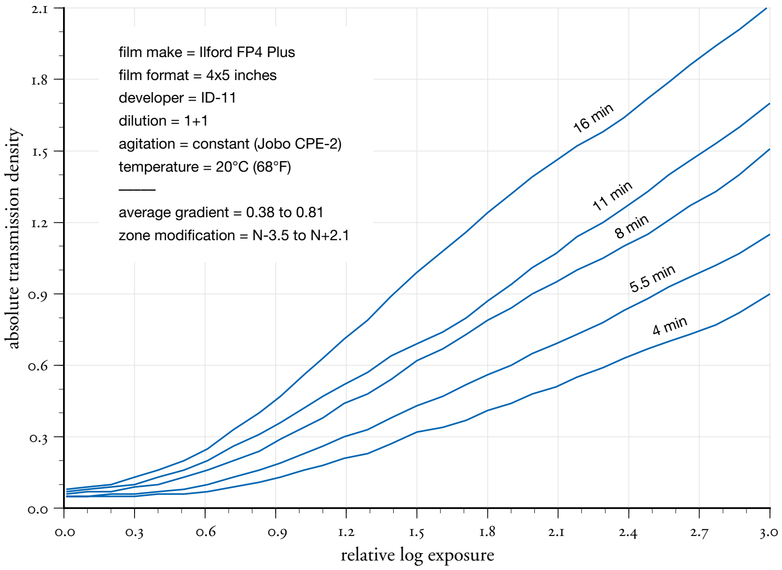
As previously mentioned, a transmission densitometer is the appropriate tool to measure the test densities. It is best to prepare a spreadsheet with six columns: the first column for the step tablet densities and the others for the negative densities of the five test films. Ideally, the 21-step tablet should have 0.15 step-to-step density increments, and the 31-step tablet should have 0.1-density increments. Be aware that your step tablet will most likely deviate slightly from these anticipated values. This is also true for calibrated step tablets. Therefore, read the densities of the step tablet itself, and list them in the first column. The test results will be more precise when charting the test data against these actual values.

Read the densities of the five tests, and fill them into the spreadsheet. My densitometer has a calibration button to 'zero' out the measurements, because it does not have an internal light source of known intensity for transmission density readings. In other words, it can be used with different light sources and allows for relative and absolute density measurements. If your equipment has a similar feature, then take the first reading with nothing in the light path, push the 'zero' button, and then, continue to take all the measurements. This will enable you to measure the 'base+fog' density of the test negatives. If you 'zero' the measurements to a blank piece of the film before taking any readings, then all base+fog densities are equalized, and you would be unaware of any fog increase due to development time. If your densitometer does not have a 'zero' button, which is most likely the case if it has its own light source, then you can be assured that your readings are absolute values and no correction is required.

The typical measurement accuracy of a standard densitometer is ±0.02 density, with a reading repeatability of ±0.01 at best. This is a more than adequate

**Measuring Density**
Reliable density measurements are best taken with a densitometer, but the investment is not always justifiable for occasional use. Some darkroom meters have the added capability of measuring transmission densities, but even simple darkroom meters can be calibrated to take density measurements. To do that, use a transmission step wedge, while fixing enlarger magnification and lens aperture, and relate all densities to meter readings. As long as the enlarger settings are repeated, relatively accurate density measurements are possible.

fig.5 A 'family of curves' illustrates how the development time changes the negative transmission density.



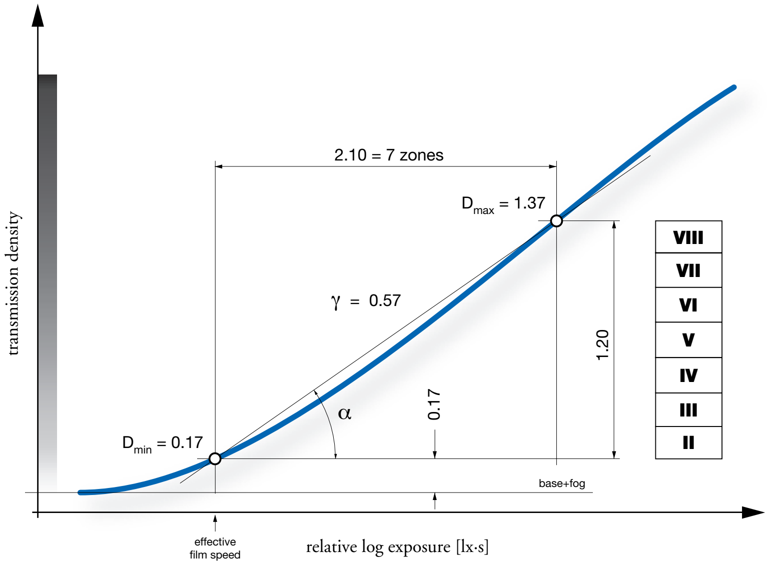


fig.6 Film exposure and development have been adjusted to work in harmony with the Zone System. The speed point has been raised to a density of 0.17 to secure proper shadow exposure. In this example, the development has been adjusted to fit a normal subject brightness range of 7 zones into a fixed negative density range of 1.20, which is a normal range for diffusion enlargers and grade-2 paper. Development modifications will allow other lighting conditions to be accommodated for them to fit the same negative density range.

measurement performance for a film development test. In addition, be aware that the Stouffer step tablet repeats step 16, and so we only need one reading for this density. Feel free to average the two readings if you find them to be slightly different.

A spreadsheet is a good way to collect and view numerical data, but you need to graph individual tests in order to evaluate the results more closely. A blank form, to graph the test data, is included in the 'Tables and Templates' chapter at the end of the book. You may employ a computer for this task, however, it is important that you keep the same axis scales as the supplied graph. Otherwise, you will get false results from the overlays we are about to use. The relative log exposure is traditionally plotted on the horizontal axis and the transmission density is plotted on the vertical axis. The major ticks are in increments of 0.3 unit steps, which correlate conveniently with 1 stop of exposure. The family of curves will look similar to our example in fig.5 once the numerical data has been successfully transferred to the graph.

### Evaluating the Data

With the aid of an overlay provided in 'Tables and Templates', you will have to take two types of measurement per curve, in order to evaluate the data (see fig.8). One is the average gradient, and the other is the relative log exposure of the speed point.

The average gradient is simply the ratio of the density range over the log exposure range. Film manufacturers and Zone System practitioners agree with the above definition of average gradient, but they differ when it comes to the selection of the boundaries for the calculation.

In fig.2, we saw how the ISO standard defines normal development as a log exposure range of 1.30 and a density range of 0.80, measured at a 0.10 shadow density. We will now replace these values with our Zone System target values as explained in 'Creating a Standard'. Fig.6 illustrates the change, which will better suit the Zone System and fine-art photography. First, we use our minimum shadow and speed-point density of 0.17. This ensures proper shadow exposure, even when development time is reduced to support high-contrast scenes. Second, we use our standard fixed negative density range of 1.20 (pictorial range). This covers the entire paper exposure range, from the beginning of Zone II to the end of Zone VIII, for normal graded papers printed with a diffusion enlarger. This, combined with a minimum shadow density of Dmin = 0.17, fixes the maximum highlight density at Dmax = 1.37. In addition, it also sets the normal log exposure range to 2.10, since we need 7 subject brightness zones to expose the 7 paper zones above, and each zone is equivalent to 0.3 log exposure. The normal average gradient can be calculated as 1.20 / 2.10 = 0.57.

The 'Tables and Templates' chapter also includes an overlay called 'Film Average Gradient Meter', which is a handy evaluation tool based on our Zone System standard. The use of the 'Film Average Gradient Meter' overlay is shown in fig.7, as it is applied to the 8-minute development test. The other curves have been removed for clarity. The overlay is placed on top of the graph in a way that the 'base+fog density' line is parallel to the grid, but tangent to the toe of the curve. The overlay is then moved horizontally until the effective film speed for 'Zone I·5 = 0.17' intersects with the curve at the speed point. Fig.7 shows the overlay in this final position at which the reading can be taken. Take the average gradient reading as close to the 'Zone VIII·5 = 1.37' density as possible. In this example, 0.55 is the average gradient for the 8-minute curve. Before you move or put the template away, you need to measure the relative log exposure at the 'effective film speed' marker. In our example, 0.80 is the log exposure that

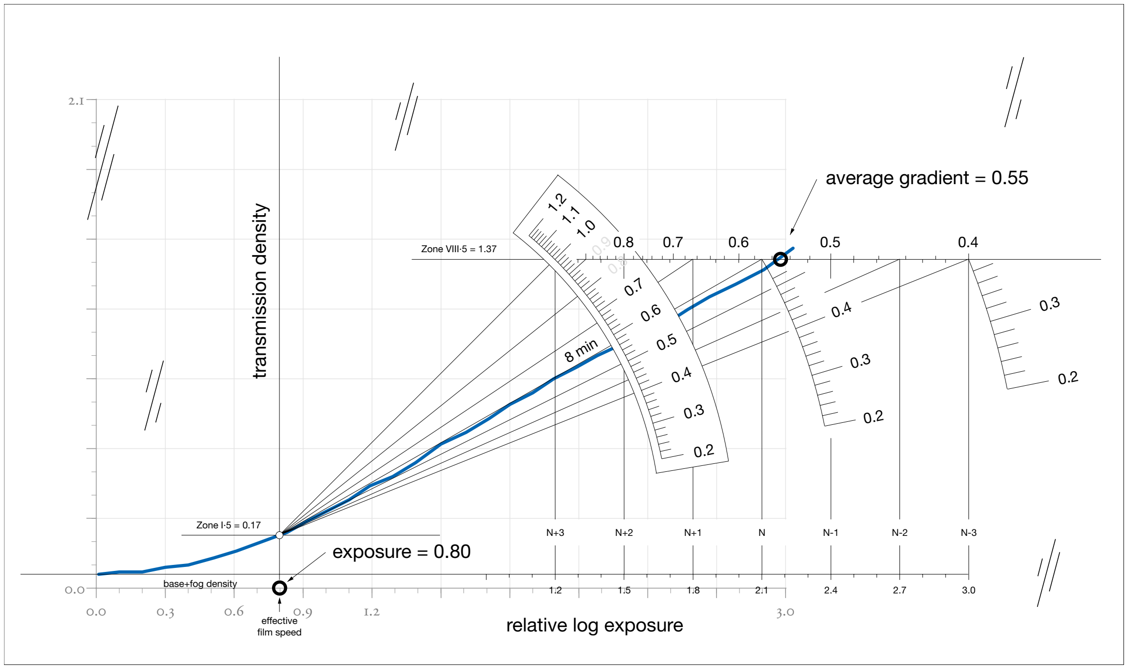


fig.7 As an example, the transparent 'Film Average Gradient Meter' overlay is used to measure the average gradient and the relative log exposure of the effective film speed for the 8-minute characteristic curve. This is done for all characteristic curves in fig.5 and the results are shown in fig.8.

created a minimum shadow density of 0.17. Record the average gradient and the relative log exposure in a table similar to the one shown in fig.8.

Evaluate the rest of the test curves in the same way and record all readings. When finished, you will have a valuable table showing the entire test data.

### Predicting Development Times

We are beginning to close the loop, and we are finally getting to chart some of the results, which will guide us to use our film effectively. The ability to precisely predict development times, in order to cope with many lighting scenarios, is a major advantage. We have now collected enough data to start filling out the 'Film Test Summary' template. Again, a blank form is included in 'Tables and Templates'. It has four sections, and we will use them in sequence.

In fig.9a, the average gradient is plotted against the development time. We conducted five development tests, and therefore, we have five data points. Draw a point for every average gradient, which you measured with the 'Film Average Gradient Meter' for 4, 5.5, 8, 11 and 16 minutes of development time. In our example in fig.7, we measured an average gradient of 0.55 and that is where we draw a point on the 8-minute line. Now, draw a smooth curve through the data points. I use a computer to 'curve fit' the line, but there are other options. Feel free to create it freehand, use a bend ruler, or use a set of French Curves, available from any drafting supply store for a small outlay. The point is that you need an averaging line through the data points; how you get there is irrelevant. You see from fig.9b how this can help determine the appropriate development time for any average gradient.

The relationship between development compensations in Zone System 'N' terms and the average gradient was explained in 'Creating a Standard'. Fig.10 shows the relationship in the form of a graph, a table and two equations. I used the values of the small table to mark the smooth curve in fig.9b at development expansion and contractions from N-2 to N+2. We can go a step further by plotting the 'N' values directly against the development times, as illustrated in fig.11. There is little difference to the previous graph, but the five average-gradient values from the test were first converted to 'N' values. To do that, either use the graph in fig.10 to estimate the closest 'N' value for each average gradient, or, if you are more comfortable with math, compute the 'N' value with the equation listed there. If you are comfortable thinking of development

### Precise Film Test Procedure Overview

1. **Exposure**
   Using the film's advertised speed, fill 5 sheets or rolls of film with identical exposures of a transmission step tablet.
2. **Development**
   Develop each film for 4, 5.5, 8, 11 and 16 min, respectively, and process normally.
3. **Collect the Data**
   Measure the average-gradient and relative log-exposure values of each film.
4. **Predict Development Time**
   Chart average-gradient values against their respective development times to estimate the time required to achieve a desired negative contrast.
5. **Predict Effective Film Speed**
   Chart average-gradient values against their respective log exposures, and fill another test film with increasing exposures before developing it normally. Find the speed point and align relative log exposures with the ISO scale to estimate the effective film speed for any subject brightness range.

| dev time [min] | average gradient | relative log exp |
|---|---|---|
| **4** | 0.38 | 1.23 |
| **5.5** | 0.45 | 0.97 |
| **8** | 0.55 | 0.80 |
| **11** | 0.62 | 0.63 |
| **16** | 0.81 | 0.58 |

fig.8 The results from the development test in fig.5 are recorded in a table.

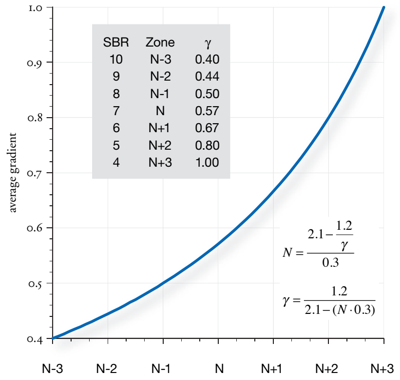


fig.10 Average gradient and Zone System compensations can be estimated or calculated. See 'Creating a Standard' for details.

compensations in terms of N- or N+, you may find the graph in fig.11 more useful than the graph in fig.9b. Some people find this easier than thinking of target contrast in terms of average gradient. The result is the same; it is just presented in a different way.

With these graphs at hand, predicting accurate development times has become simple. However, care must be taken not to alter any of the other significant variables. Be sure to keep temperature, chemical dilution, film/developer ratio and agitation as constant as possible.

**Predicting Effective Film Speeds**

The final task is determining the effective film speeds for all developments. Of course, we would like to have these effective film speeds in ISO units, but doing this directly is a complex task and involves laboratory equipment not available to a fine-art photographer. The only data obtainable at this point are the relative log exposures required to develop the speed point densities as measured with the 'Film Average Gradient Meter' in fig.7. We will convert these relative log exposures to effective film speeds in a moment.

First, plot the test values from fig.8 in terms of average gradient versus relative log exposure of their effective film speeds, as shown in fig.12a, and draw a smooth line through the data points. Then, as shown in fig.12b, find the intersection of the N-development's average gradient (0.57) and the curve. Project it down to the relative log exposure axis. There you will find the relative log exposure for an N-development (0.75), as marked with the gray circle. This log exposure is equivalent to the normal EI, which is the normal effective film speed for this film/developer combination. However, to get the normal EI in terms of ISO units, we must conduct one last test.

1. Use an evenly illuminated Kodak Gray Card as a test target (see fig.12c).
2. Set your lightmeter to twice the advertised film speed and take a reading from the card.
3. Place the reading on Zone 1.5 and determine the exposure for an aperture closed down by 4 stops. Keep the exposure time within 1/8 and 1/125 of a second or modify the aperture.
4. Make the first exposure.
5. Open the lens aperture to increase the exposure by 1/3 stop, and make another exposure.

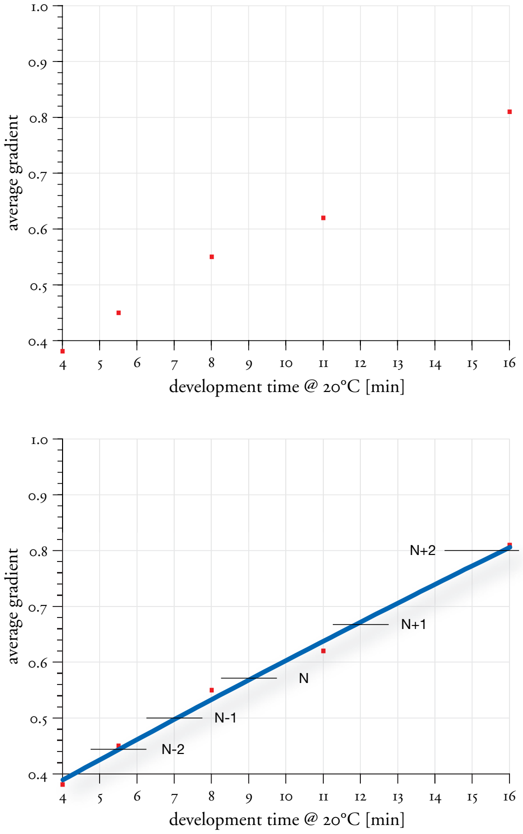


fig.9a-b The average gradient for each test is first plotted, then a smooth curve fit is applied and the typical Zone System development compensations are marked for reference.

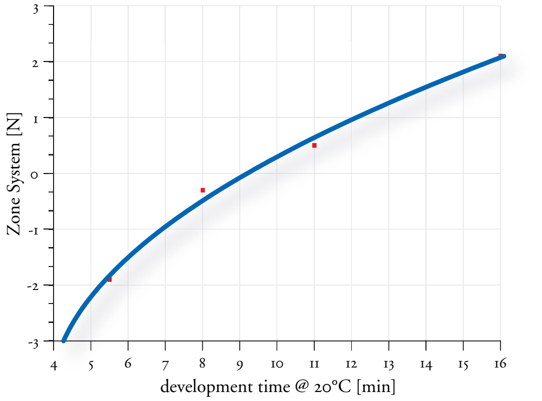


fig.11 A practical development chart is created, when the 'N' values are plotted against the development time.

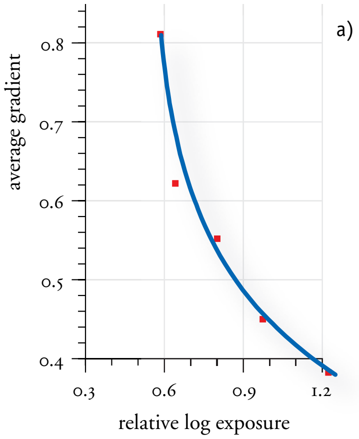


fig.12a (top left) The test values from fig.8 are plotted in terms of average gradient versus relative log exposure, and a smooth curve is drawn through the data points.

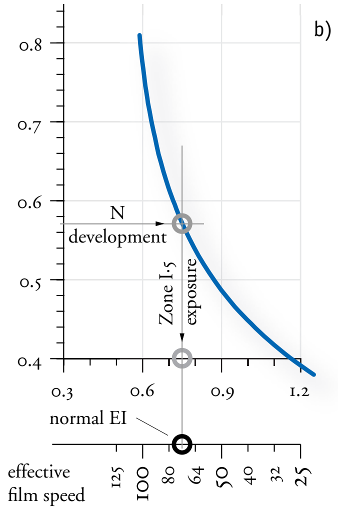
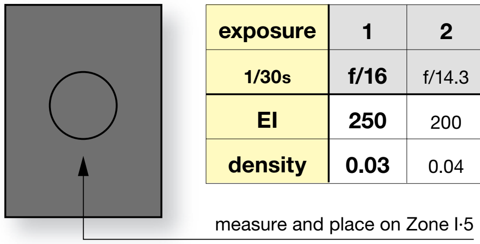


fig.12b (top center) Find the intersection of the average gradient for N and the curve. Project it down to the relative log exposure axis to find the relative log exposure for N.

c)



| **exposure** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|
| **1/30s** | **f/16** | f/14.3 | f/12.7 | **f/11** | f/10.1 | f/9.0 | **f/8** | f/7.1 | f/6.3 | **f/5.6** |
| **EI** | **250** | 200 | 160 | **125** | 100 | 80 | **64** | 50 | 40 | **32** |
| **density** | **0.03** | 0.04 | 0.06 | **0.09** | 0.12 | 0.15 | **0.18** | 0.22 | 0.27 | **0.33** |

box speed

normal EI

fig.12c (bottom) Zone I·5-exposures in 1/3-stop increments are evaluated to determine the ISO speed for a normal EI. This is aligned with the relative log exposure in fig.12b.

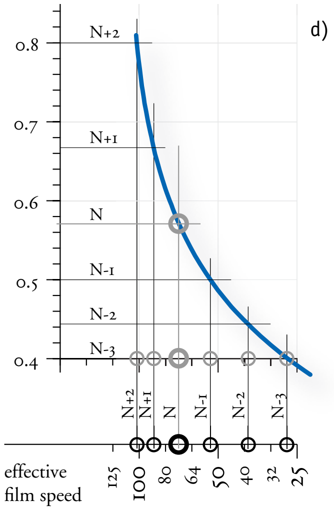


fig.12d (top right) More average-gradients values are projected onto the bottom axis to determine the missing film speeds for other Zone System developments.

6. Repeat step (5) nine times to simulate different effective film speeds over a range of 3 stops in 1/3-stop increments, but don't change the exposure time.
7. With roll film, set your lightmeter back to the advertised film speed and expose the remaining frames with Zone-V exposures.
8. Develop the film for the time established as a normal N-development in fig.11. Process and dry the film normally.
9. Using a densitometer, start with the first frame and twice the box speed, count down 1/3 stop for every frame until you find the frame with a transmission density closest to a speed-point density of 0.17 (Zone I·5). The film speed used to expose this frame is your customized 'normal EI' (fig.12c).

We can relate the data from the curve in fig.12b to film speeds, because the relationship between log exposures and ISO speeds is known. A 0.1 log exposure difference is equal to a 1/3 stop difference in film speed. The effective film speed scale below the relative log exposure axis illustrates this relationship. It uses the normal EI as a starting point, and we are now ready to specify the effective film speed for any average gradient. In fig.12d, the typical values for N-3 to N+2 were projected on the curve and onto the log exposure axis, where they were marked with gray circles. Extending the projection to the effective film speed scale yields the EI for all development compensations this particular film/developer combination is capable of.

The graph must be cleaned up a bit so the data is readily available in the field. An improved graph is shown in fig.13. The 'N' values are plotted directly against the effective film speed. We can see how the film sensitivity decreases with development contraction. In other words, the film requires significantly more exposure to maintain constant shadow densities, when development time is reduced.

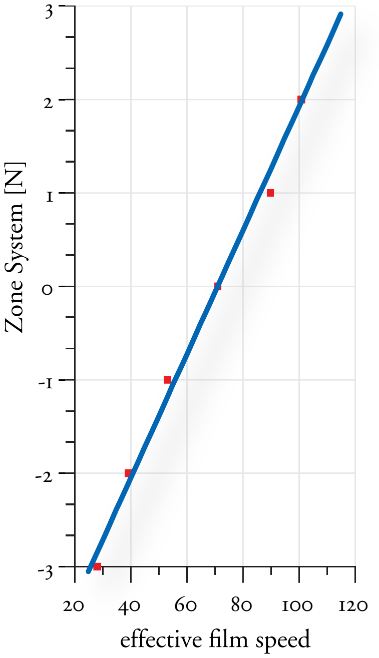


fig.13 This improved graph is a useful guide for Zone System exposures.

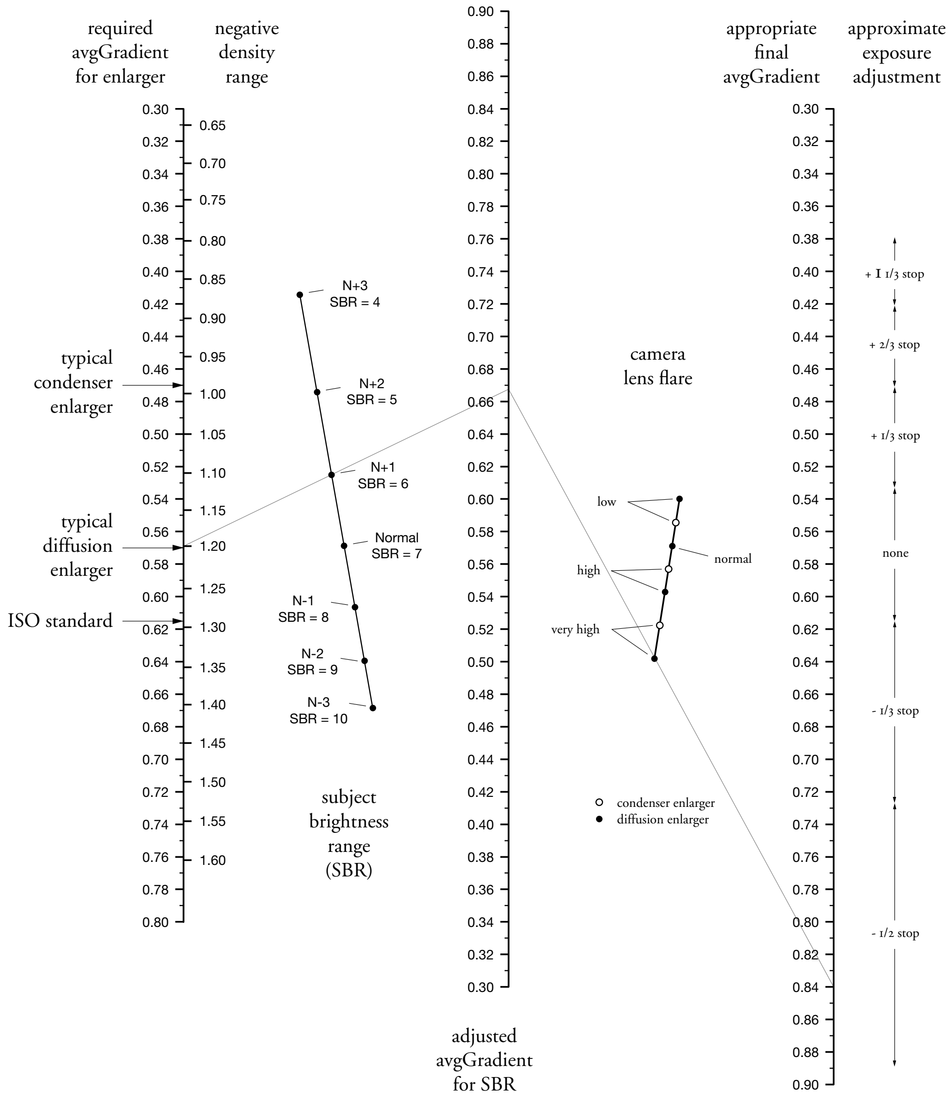


fig.14 This contrast control nomograph, based on a Kodak original, is designed to determine the appropriate average gradient and film exposure adjustment for different enlargers, lighting situations and camera flare. Select the required average gradient for your enlarger that gives a negative density range, fitting well on normal contrast paper. Draw a straight line through the subject brightness range and extend until it intersects with the adjusted average gradient. Draw another straight line through your typical camera flare value and extend it to find the final average gradient and the approximate exposure adjustment. One example is shown for a typical diffusion enlarger, a slightly soft (N+1) lighting condition and the use of an older, uncoated lens with very high flare. The average gradient is raised from 0.57 to 0.67 due to the lighting condition. The lens flare requires a further increase to 0.84, and exposure must be reduced by 1/2 stop.

## Equipment Influence

You may want to lower the average gradient if you are working with a condenser enlarger. Their optics make a negative seem to be about a grade harder, but print with the same quality once the negative density range is adjusted. Use a fixed negative density range of 0.90 as a starting point for condenser enlargers. In addition, you may also want to make other adjustments to target average-gradient values if you have severe lens and camera flare, or if you experience extremely low flare. Fig.14 will help to approximate a target average gradient and exposure compensation, but I have not found any need to do so with any of my equipment.

## Conclusion

A precise film-speed and development test is not a simple task. It requires some special equipment, some time, patience, practice and several non-photographic related skills. But the rewards are high. Fig.13 contains all information required to properly expose a given film under any lighting condition and then develop it in a given developer with the confidence to get quality negatives. These negatives will print well on a standard ISO grade-2 paper when using a diffusion enlarger. In my view, all the hard work has paid off. There is no need to worry about exposure and development anymore. No need to bracket exposures endlessly or to hope that it will 'work out'. The occasional gremlin aside, it will. Now, all attention can be directed entirely towards the interaction of light and shadows, making and not taking a photograph, and therefore ultimately producing a piece of art.

Nevertheless, if this is all too much technical tinkering and you prefer to spend your time creating images, then remember that even a simplified method, as shown in 'Quick and Easy' or 'Fast and Practical', will improve negative and print quality significantly.

# Influence of Exposure and Development

## Expose for the shadows and develop for the highlights

Even with the best planning and testing, we are sometimes forced to work under less than perfect conditions. We thought we had loaded ISO 400/27° film, but actually, it was the left-over ISO 100/21° from the last model shoot, or we looked up the wrong time on our development table. Whether intentional or not, film exposure and development deviations have consequences, which must be fully understood to implement potential recovery methods and get the most from our negatives.

For more than a century, experienced photographers have advised us to expose for the shadows and to develop for the highlights. This is solid advice, proved out in the previous chapters. The lack of modern technology must have made exposure and development control far more difficult for early photographers than it is for us, and they were forced to come up with ways to avoid poorly controlled negatives. Their advice, which is still valid today, simply states that when in doubt, film should be overexposed and underdeveloped. We will first review a still valid historic study and then evaluate some typical cases of exposure and development deviation, comparing them to the intended processing and evaluate the effectiveness of recovery attempts using variable-contrast (VC) papers.

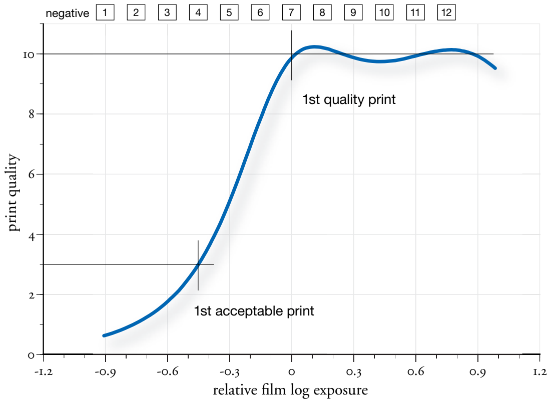
### A Historic Study

In March 1939, Loyd A. Jones published the results of his study in which he had researched the relationship between photographic print quality and film exposure. He defined print quality as the fidelity with which the brightness and brightness differences in the original scene are reproduced in the illuminated positive, as viewed by an observer and certain psychophysical characteristics of the observer's visual sensory and perceptual mechanisms.

He considered subjective factors in addition to those strictly objective or physical in nature. The test was conducted in the following manner: A normal contrast scene transparency was chosen as a test subject to guarantee consistent lighting conditions. Twelve exposures were made in 1/2 stop increments, creating film exposures ranging from severely underexposed to severely overexposed. The exposed materials were developed under identical conditions, and experienced printers were instructed to make the best possible print from each negative. To do so, a group of prints was made from each negative by varying print exposure and contrast, keeping all other print processing parameters consistent.

From each group, one was chosen as the best that could be made from that negative. Thus, a series of twelve prints from differently exposed negatives was obtained. Several observers were asked to subjectively judge the print quality of these twelve prints on a scale from 0-10. In fig.1, the result of this evaluation is shown. Print 4 was the first to be judged as acceptable, but only prints from negative 7 or above received the highest quality rating. From this study, it becomes clear that print quality is highly dependent on sufficient film exposure. The study was repeated with three different films, all leading to the same conclusion.

fig.1 A historic study proved that final print quality increases with film exposure.



### The Case Study

Loyd's historic study was an effective but laborious way to prove the point. A much simplified version can also illustrate the influence of film exposure and development on print quality. Figures 3 and 6 show the same print from a negative that was exposed and

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50027-2

fig.2a Overexposing film by 1 stop increases all negative densities by similar amounts, and only requires a small paper contrast correction to print well. Print quality is not degraded. A relatively high local average gradient provides increased shadow contrast and separation.

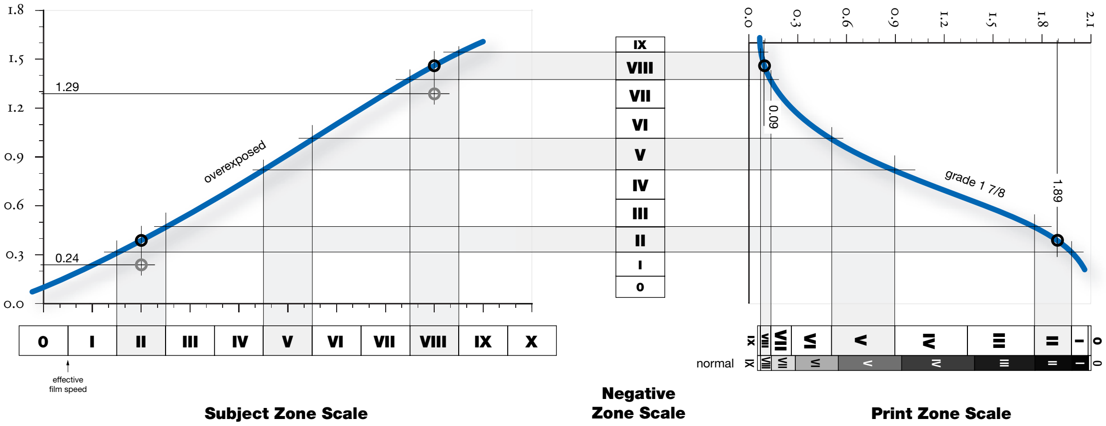
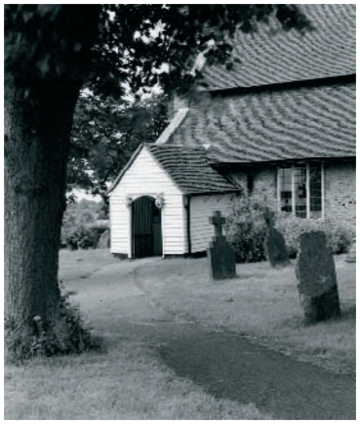
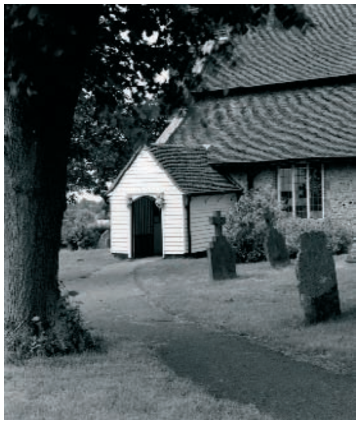


fig.2b (right) Film with normal development but overexposed by 1 stop and slightly corrected print contrast. This print has more shadow detail separation than the normal print.



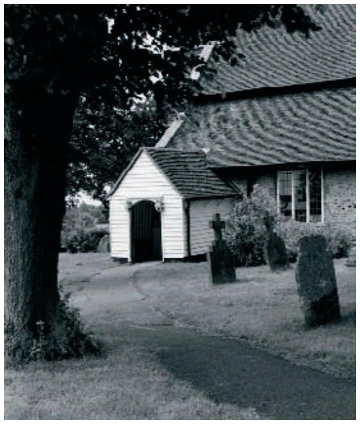
overexposed

fig.3 (middle) Normal film exposure and development printed on grade-2 paper as a comparison. This print has a full tonal scale and plenty of highlight and shadow detail.



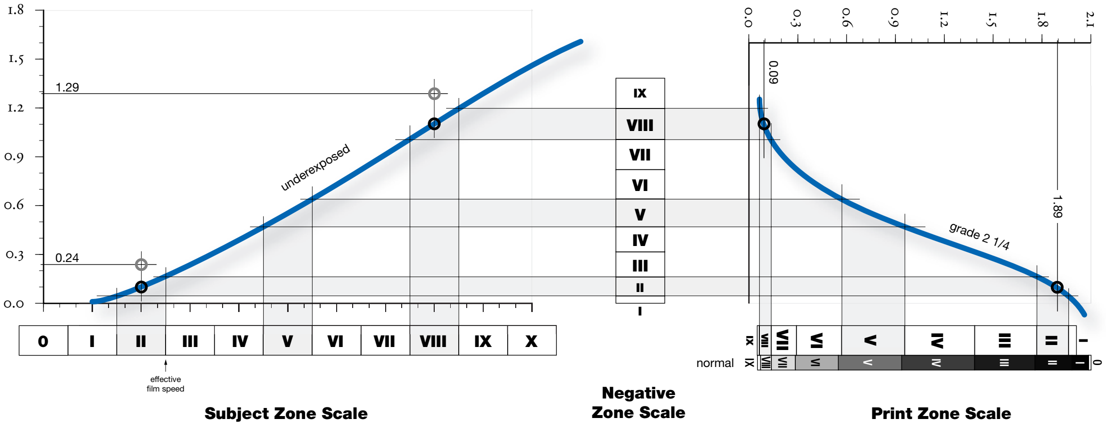
normal exposure

fig.4b (far right) Film with normal development but underexposed by 1 stop and slightly corrected print contrast. This print lost shadow detail but is acceptable for standard photography.



underexposed

fig.4a Underexposing film by 1 stop decreases all negative densities by similar amounts but loses important shadow detail.



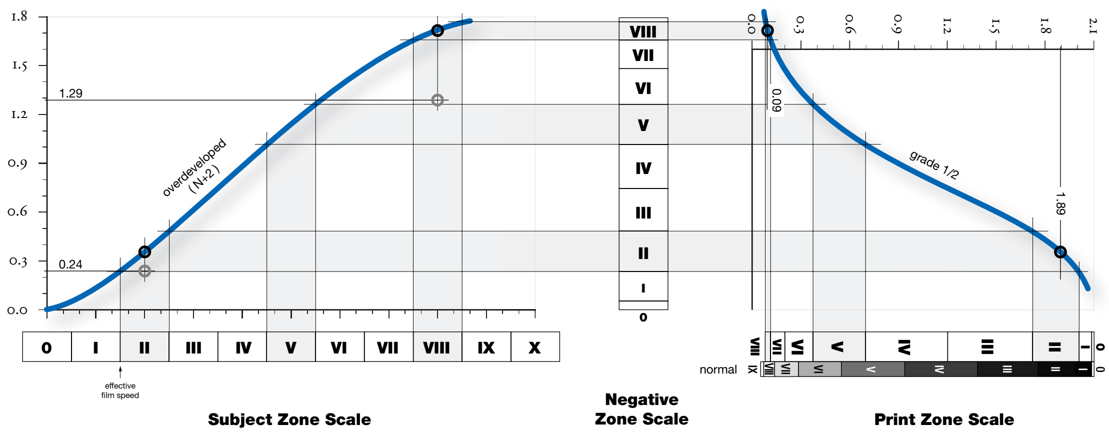
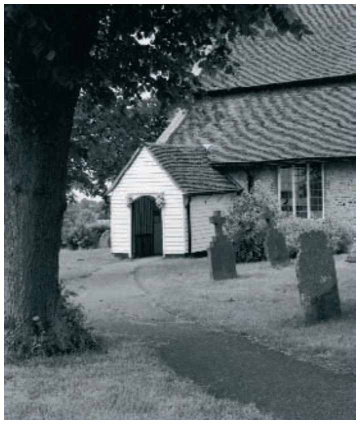
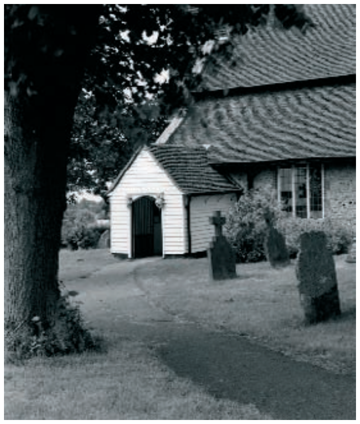


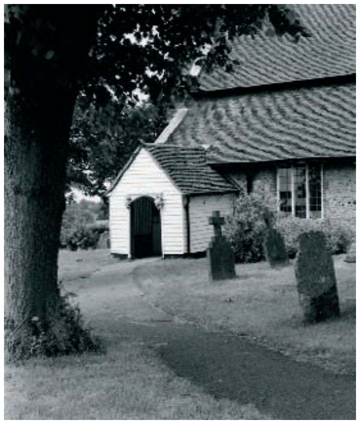
fig.5a An overdeveloped film has dense highlights and increased shadow densities. In addition, highlight separation can suffer from shoulder roll-off, but usually an 'acceptable' print can be made by compensating with a soft paper grade.



overdeveloped



normal development



underdeveloped

fig.5b (far left) Film with normal exposure but overdeveloped by 75% and printed on grade-0.5 paper. This print appears less sharp, because it lacks highlight and midtone contrast, but shows increased shadow detail.

fig.6 (middle) Normal film development and exposure printed on grade-2 paper as a comparison. This print has a full tonal scale and plenty of highlight and shadow detail.

fig.7b (left) Film with normal exposure but underdeveloped by 40% and printed on grade-3.5 paper. This print is almost identical to the normal print but has slightly lighter midtones.

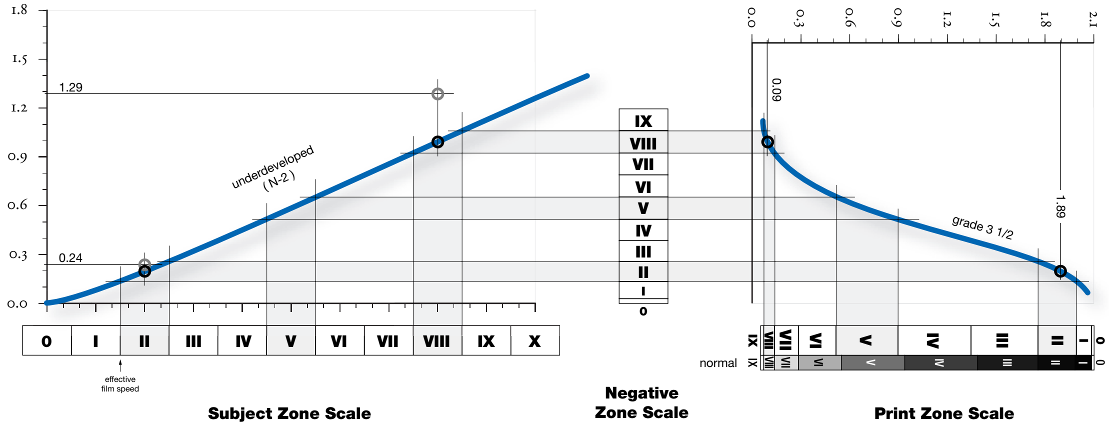


fig.7a An underdeveloped film has weak highlight densities, but a good print can still be made by compensating with a harder paper grade.

developed normally for comparison. As expected, it printed well on a grade-2 paper. For the film exposure, the lower half of the dark steel gate in the shadowed entrance to the church was placed on Zone III, and the white woodwork above fell on Zone VIII. While preparing the test prints, an effort was made to keep the print densities constant for these two areas. This is consistent with the assumption in Loyd's study that an experienced printer would aim to optimize important highlight and shadow densities regardless of negative quality. This makes for a realistic test, and it greatly compensates for the influence of film exposure and development deviations. However, we are more interested in the practical consequences of printing less than perfect negatives with variable-contrast papers than in a scientific study.

## Exposure Deviation

Fig.2b shows a print from a negative that was overexposed by 1 stop and slightly contrast corrected during printing, as described above. Fig.2a illustrates that overexposing film by 1 stop pushes shadow and highlight densities up the characteristic curve, increasing all negative densities by similar amounts. Only a small paper contrast correction was required to make a quality print. However, the toe of the characteristic curve has lost its typical shape and has been replaced with a higher average of local shadow gradient, which indicates increased shadow contrast and separation, as is most visible in the upper half of the tree trunk. It will not be difficult to make a quality print from this overexposed negative, leaving others to wonder what your secret is to achieve this level of shadow detail.

The 1-stop underexposed print in fig.4b and its graph in fig.4a tell a different story. Shadow detail has suffered from the lack of exposure. Underexposing film by 1 stop pushes shadow and highlight densities down the characteristic curve, decreasing all negative densities by similar amounts, but rendering shadow densities too thin to retain enough detail for a quality print. Nevertheless, a slightly increased paper contrast has salvaged the print to a point acceptable for standard photography, where the untrained eye may not find objection, although a quality print can never be made from this underexposed negative.

When in doubt about exposure, I prefer to err on the side of negative overexposure for fine-art prints. There are some unwanted side effects, such as longer printing times and potentially larger grain, which is more of a concern for 35 mm users, but the final image will be of high quality. On the other hand, an underexposed negative lacks the shadow detail required for a fine-art print, although it can still be used to make an acceptable image.

## Development Deviation

Fig.5b shows a print from a negative that was exposed normally but overdeveloped by 75% to simulate an N+2 development. Fig.5a reveals that the negative highlight density increase is several times greater than the increase in shadow density. This increases the negative density range and requires a soft-grade paper to contain all textural densities. As a consequence, highlights and midtones are compressed, and shadows are expanded. The print appears less sharp, lacks highlight and midtone contrast, but shows increased shadow detail. Producing a quality print from an overdeveloped negative is difficult or impossible and requires extensive dodging and burning.

Fig.7b shows a print from a negative that was exposed normally but underdeveloped by 40% to simulate an N-2 development. In this case, a grade 3.5 paper was required to make a full-scale print from the limited negative density range and match the shadow densities of the door. Fig.7a illustrates how print highlight and shadow densities are at normal levels, but midtone densities are slightly shifted towards the highlights. The same can be seen in the print, which is almost identical to the normal print but has slightly lighter midtones. It is not difficult to make a quality print from an underdeveloped negative.

In a side-by-side comparison, the underdeveloped negative printed on hard paper has more sparkle than the overdeveloped negative printed on soft paper. However, underdevelopment results in a loss of shadow detail if not compensated with increased film exposure, as it would not be if the underdevelopment was accidental. On the other hand, the overdeveloped negative has plenty of shadow detail, but the low paper contrast appearance is just not attractive enough to consider this salvage technique for quality prints.

In conclusion, the advice from the old masters of overexposing and underdeveloping film, when in doubt, has proven to be sound even when using VC papers. The technique insures plenty of shadow detail, high local contrast and apparent sharpness.

# Exposure Latitude

## What can we get away with?

A good negative has plenty of shadow and highlight detail and prints easily on normal graded paper. We aim to create such a negative by controlling film exposure and development as closely as we can. Sufficient film exposure ensures adequate shadow density and contrast, and avoiding film overdevelopment keeps highlights from becoming too dense to print effortlessly.

Irrespective of our best efforts, exposure variability is unavoidable, due to various reasons. Shutters, apertures and lightmeters operate within tolerances, lighting conditions are not entirely stable, films don't respond consistently at all temperatures and all levels of illumination, and no matter how hard we try, there is always some variation in film processing. Sometimes we get lucky, and the variations cancel each other out. Other times, we are not so lucky and they add up.

Considering all this, it is surprising that we get usable negatives at all. Conveniently, modern films are rather forgiving to overexposure. The 'film exposure scale' is the total range of exposures, within which,

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50028-4

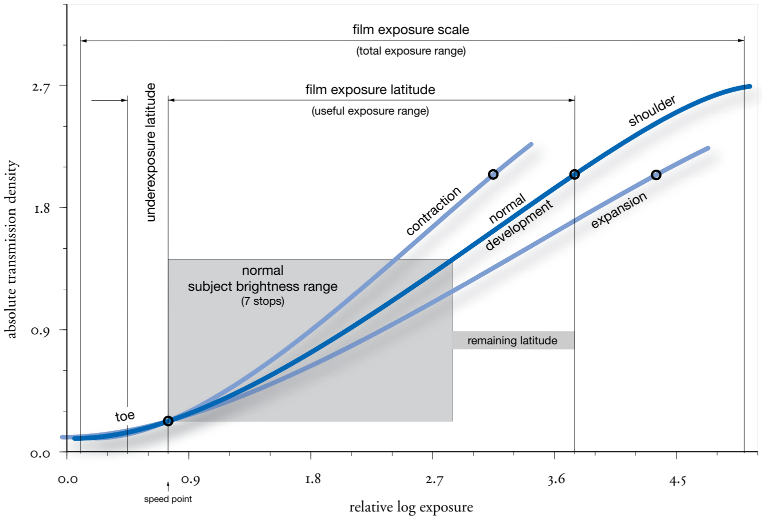


fig.1 Film exposure latitude is defined as the range of exposures over which a photographic film yields images of acceptable quality.

film is capable of rendering differences in subject brightness as identifiable density differences (fig.1). Compared to the subject brightness range (SBR) of an average outdoor scene (about 7 stops), the typical film exposure scale is huge (15 stops or more). However, the entire exposure scale is not suitable for quality photographic images. The exposure extremes in the 'toe' and 'shoulder' areas of the characteristic curve exhibit only minute density differences for significant exposure differences, providing little or no tonal differentiation or contrast.

Therefore, the useful exposure range, suitable for recording quality photographic images, is somewhat smaller than the total exposure range. Still, it is significantly larger than the normal subject brightness range and, consequently, offers leeway or latitude for exposure and processing errors. The limits of the film exposure latitude depend on how much image detail is required in shadows and highlights in order to consider it a quality print. This debate has already filled numerous papers and volumes of books on photographic image science. For practical photography, we can define the film exposure latitude as the range of exposures over which a photographic film yields images of acceptable quality. Most modern films have an exposure latitude of 10 stops or more after normal processing, and if you process your own films, this range can be extended substantially.

## Controlling Latitude

Exposure latitude is a material characteristic influenced by development. Film exposure latitude is governed partially by the film's material characteristics but mainly by film development. In general terms, fast films have more exposure latitude than slow films, and latitude decreases with extended development. The shorter the film development, the wider the exposure latitude (fig.1).

Zone System practitioners modify film development times (expansion and contraction) to control the useful exposure range (latitude) on a regular basis. However, they do so in an effort to match the exposure range of the film with the subject brightness range of the scene and not to provide compensation for exposure errors. It comes as no surprise that Ansel Adams (1902-1984), the father of the Zone System, never used the word 'latitude' in his famous three-volume series of books (*The Camera, The Negative, The Print*). Nevertheless, when in doubt, it is better to err on the side of underdevelopment, allowing for more exposure latitude. A 'soft' underdeveloped negative has better highlight separation and is, therefore, easier to print than a harsh overdeveloped negative.

fig.2 (right) A considerable portion of the film exposure latitude is consumed by the subject brightness range. As a result, the remaining latitude depends largely upon the subject contrast.

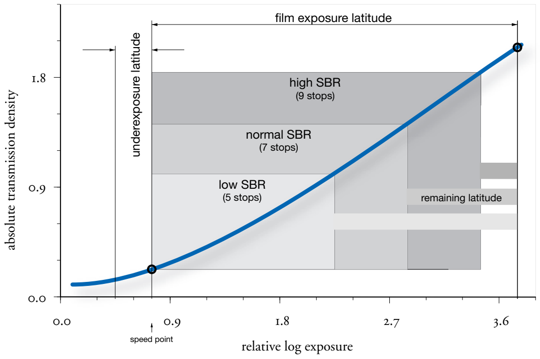
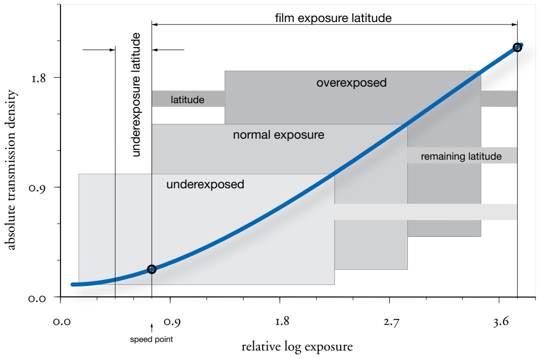
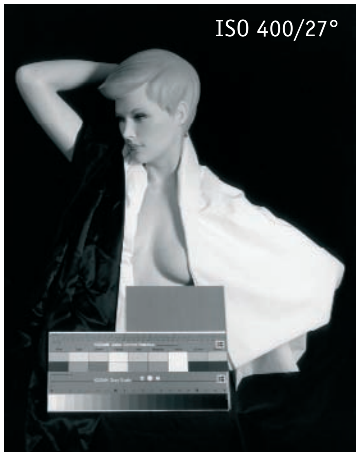
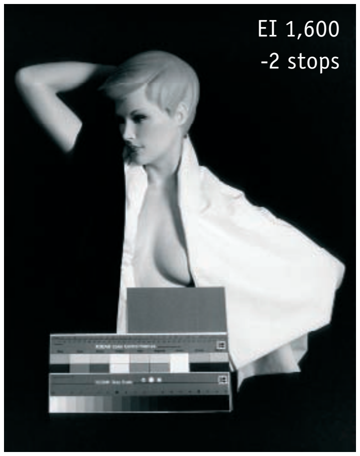
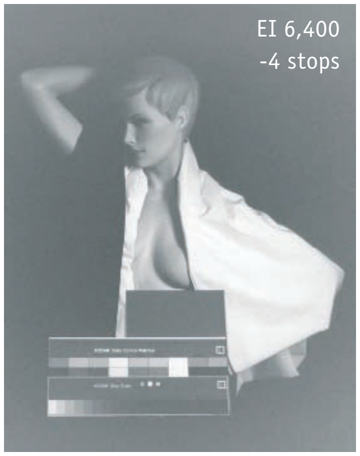


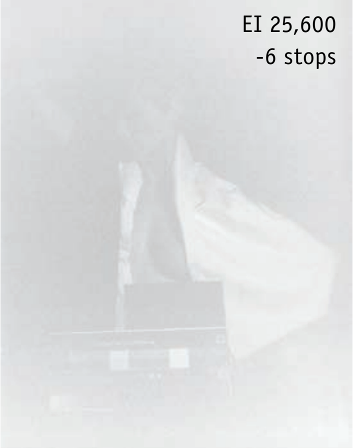
fig.3 (far right) Strictly speaking, film has no latitude towards underexposure unless, for the sake of getting some kind of an image, we are willing to sacrifice image quality and the loss of shadow detail.

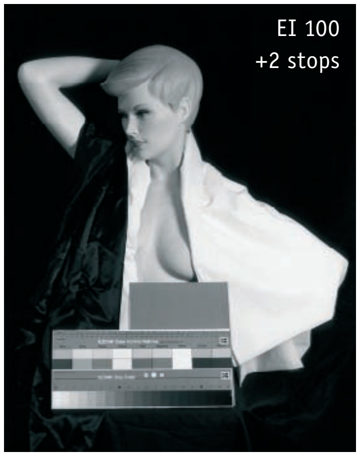


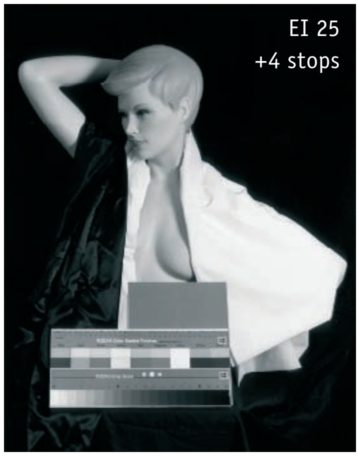

ISO 400/27°


EI 1,600
-2 stops


EI 6,400
-4 stops


EI 25,600
-6 stops


EI 100
+2 stops


EI 25
+4 stops

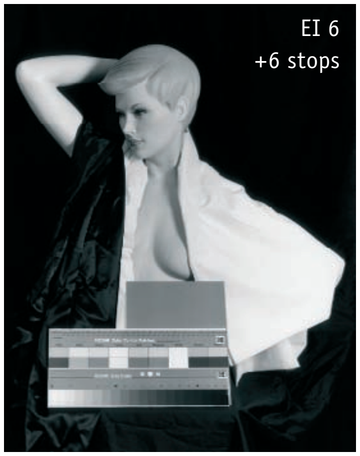

EI 6
+6 stops

fig.4 These images illustrate the influence of under- and overexposure on image quality. All prints were made of negatives from the same roll of film, highlight densities were kept consistent through print exposure and an effort was made to keep shadow densities consistent by modifying print contrast. Prints from the overexposed negatives show no detrimental effect on image quality. Prints from the underexposed negatives show a significant loss of image quality.

A considerable portion of the film exposure latitude is consumed by the subject brightness range. As a result, the remaining latitude depends largely upon the subject contrast. The higher the subject contrast, the smaller the remaining latitude (see fig.2). The subject brightness range of a high-contrast scene, with deep shadows and sunlit highlights, is often beyond the useful exposure range of a normally processed silver-based B&W film. This leaves no latitude for exposure errors. In cases like this, normal development creates highlights too dense to print on normal paper without some darkroom manipulations or extended highlights with reduced tonal separation. However, a reduction in film development (expansion) keeps the highlights from building up too much negative density, which yields a negative that is much easier to print.

When B&W photographers depend on lab services to process their films, they usually give up latitude control through film development. At this point, the choice of film remains the only control over exposure latitude. As stated above, the faster the film, the wider the exposure latitude. Therefore, films like Delta-400, HP5, TMax-400 or Tri-X Pan are good choices, but there is an additional option.

Normally developed Ilford XP2, a dye-based B&W film, has more exposure latitude than any other film I have used. This film has a particularly extended and delicate highlight response. I never came across a subject brightness range that proved to be too much for this fine-grain film. XP2 is developed using the common Kodak C41 color negative process, and consequently, any consumer lab can develop the film. XP2 negatives print well and with ease on harder than normal contrast papers. Expose XP2 at EI 200 to get more shadow detail, and use it for normal and high-contrast subjects. However, XP2 is too ‘soft’ for low-contrast subjects, even if developed for twice the normal development time.

Kodak and Fuji also make dye-based B&W films, but they are quite different products. These films are optimized for monochrome printing on color paper in consumer labs, but they do not print as easily on variable-contrast B&W paper as Ilford XP2 does.

## Latitude and Image Quality

In figures 1 and 2, we looked at the film exposure latitude as something exclusively affecting overexposure, keeping shadow exposure constant. And, ignoring a slight increase in grain size, there is no loss of visible image quality with overexposure, unless the overexposure is exorbitant, at which point enlarging times become excessively long.

Strictly speaking, film has no latitude towards underexposure (see fig.3), because film speed is defined as the minimum exposure required to create adequate shadow density. Underexposed film does not have adequate shadow density. Practically speaking, however, film has some underexposure latitude if we are willing to sacrifice image quality. For example, a loss in image quality might be tolerated where any image is better than none, as may be the case in sports, news or surveillance photography.

The images in fig.4 illustrate the influence of under- and overexposure on image quality. All prints were made of negatives from the same roll of film and, consequently, received the same development. The base print (ISO 400/27°) was made from a negative exposed according to the manufacturer’s recommendation. The other six prints were made from negatives that have been under- and overexposed by 2, 4 and 6 stops. In these prints, highlight densities were kept consistent through print exposure, and an effort was made to keep shadow densities as consistent as possible by modifying print contrast. Prints from the overexposed negatives (+2, +4 and +6 stops) show no adverse effect on image quality. Actually, the opposite is true, because shadow detail increases with overexposure in these prints. On the other hand, prints from the underexposed negatives show a significant loss of image quality (-2 stops), an unacceptable low-quality print (-4 stops), and the loss of almost all image detail (-6 stops). Obviously, film has far more latitude towards overexposure than underexposure.

The aim is to be accurate with exposure and development, knowing that there is some exposure latitude to compensate for error and variation. You can get away with underdevelopment far more easily than with overdevelopment, and you can get away with extreme overexposure better than with slight underexposure. Print quality actually improves with modest overexposure but is very sensitive to underexposure. Overdeveloped negatives will not print easily, but minute underdevelopment is easily corrected with a harder grade of paper. Film exposure latitude is what you can get away with, but when in doubt, overexpose and underdevelop.

# Pre-Exposure

## A double take on film exposure

There are occasions when subject shadows need some extra illumination, either to lessen overall contrast or to get just a hint of detail into otherwise featureless blacks. Of course, just adding some light locally, through spotlights or electronic flash, would be the best solution, but that is not always practical and sometimes impossible. Alternatively, simply increasing the exposure and reducing development may not be suitable for aesthetic reasons. This technique is always accompanied by an overall contrast reduction, adding some shadow detail, but at the cost of reduced midtone and highlight separation.

A valuable option is to precede the actual image exposure with a low-intensity pre-exposure. As the name suggests, this is a small uniform exposure, not forming an image itself, but adding some low-level density prior to the image exposure. The goal is to increase shadow density without significantly affecting midtone or highlight density and contrast. This procedure works, because the low-intensity pre-exposure has a

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50029-6

| subject Zone | exposure [units] pre | + base | = total | additional exposure [%] | [f/stop] |
|---|---|---|---|---|---|
| I | 2 | 1 | 3 | 200 | $+1\frac{2}{3}$ |
| II | 2 | 2 | 4 | 100 | +1 |
| III | 2 | 4 | 6 | 50 | $+\frac{2}{3}$ |
| IV | 2 | 8 | 10 | 25 | $+\frac{1}{3}$ |
| V | 2 | 16 | 18 | 13 | $+\frac{1}{6}$ |
| VI | 2 | 32 | 34 | 6 | $+\frac{1}{12}$ |
| VII | 2 | 64 | 66 | 3 | $+\frac{1}{24}$ |
| VIII | 2 | 128 | 130 | 2 | $+\frac{1}{48}$ |
| IX | 2 | 256 | 258 | 1 | $+\frac{1}{96}$ |

fig.1 The theoretical contribution of a Zone-II pre-exposure, in percent, halves for each increasing image Zone, until its effect becomes negligible beyond Zone V.

fig.2 Shown below are the commercially available ExpoDisc (left) and examples of homemade pre-exposure devices for a round filter system (right), which are made from a white translucent plastic. The measured exposure through the diffuser must be reduced by 2, 3 or 4 stops for Zone III, II or I pre-exposures, respectively.

EXPO/DISC
67
CD-ROM/DVD-MARKER

substantial effect on the low-level shadow exposures, but is of little to no consequence to the comparatively larger midtone and highlight exposures. The outcome of pre-exposure is a modified film characteristic, with an overall lower contrast index, but uniquely, with most of the contrast reduction confined to the shadow regions. This makes the results of pre-exposure very different to modified development or simply using variable-contrast papers.

The optimum pre-exposure is low enough to just boost, and not overtake, the shadow exposure, but this will always add enough exposure to increase the fog level of the film. The results of pre-exposure are, consequently, very similar to usage of equipment with considerable lens and camera flare. Ironically, the photographers of the last centuries benefited from accidental pre-exposure in many of their images, as their uncoated optics were prone to lens flare, which added a low-level exposure to the entire frame. Was this the secret of the old masters?

Nevertheless, for photographers who prefer using graded papers, the pre-exposure technique offers a unique opportunity to modify the film characteristic to match their fixed-contrast papers without changing development and overall negative contrast. The same is true for roll-film users, who would rather modify the negative contrast of a single frame than to rely on the overall contrast change of a variable-contrast paper. In any case, this technique requires a camera with multiple-exposure capability.

## Theory and Testing

A Zone-I pre-exposure is defined as taking a Zone-V exposure reading of a uniform subject and reducing the exposure by 4 stops. Similarly, a Zone-II pre-exposure is defined as the same exposure reading, reduced by 3 stops and so on. Fig.1 shows the theoretical contribution and overall change from a Zone-II pre-exposure to a full range image exposure. For this level of pre-exposure, those areas of the image that are placed on Zone II will receive 100% or 1 stop more light, those on Zone III will receive 50% more exposure and so on. The pre-exposure contribution, in percent, halves for each increasing image Zone, until its effect becomes negligible beyond Zone V.

To determine the actual negative response to pre-exposure, several films were tested by first applying pre-exposures of varying intensities and then photographing a Stouffer transmission tablet. All films were identically processed using the same developer, and the film characteristic curves were measured and plotted. As an example, the results for Fuji Neopan Acros 100, adding three low-intensity pre-exposures, are shown in fig.3, and they confirm the theoretical values of fig.1.

We can see from fig.3 that the pre-exposure adds significantly to the negative shadow density, while having little effect on midtone density and leaving highlight density practically untouched. However, a Zone-I, II or III pre-exposure progressively increases the negative fog level and reduces shadow contrast.

The speed point of a film is defined as having a fixed density above base and fog. Since a pre-exposure increases the negative fog level, it takes additional exposure to reach the speed-point density. Consequently, the theoretical film speed gradually decreases with pre-exposure and does not increase, as is often proposed in other photographic literature. An increase in absolute shadow density must not be confused with an increase in film speed.

Every film type has a slightly different response, depending upon the 'toe' shape of its film characteristic, suggesting that personal testing is required to determine the optimal pre-exposure intensity.

## Making Pre-Exposures

In the chapter 'Filters and Pre-exposure' in his book *The Negative*, Ansel Adams illustrates this technique with two practical examples. His technique and that of Barry Thornton, explained in his book *Elements*, differ slightly in approach, although they both make their pre-exposures through a white diffuser. These diffusers are visually opaque to prevent any image forming on the film. For that reason, diffuser filters, used to soften portraits or create misty effects, are not suitable. A piece of white translucent plastic, mounted in a square filter holder, or cut into a circle and mounted in an old filter ring, makes for an ideal diffuser, see fig.2. It is an effective and economical homemade pre-exposure device. A more expensive solution is the commercially available ExpoDisc. It sandwiches a white diffuser behind a multifaceted lens, also turning into an adaptor for measuring incident light with the aid of a TTL meter, or determining the white-balance setting for digital cameras.

To ensure an accurate pre-exposure calculation, the diffuser is placed over a spotmeter, and an exposure reading is taken, using the same incident lighting conditions as will occur when the diffuser is placed over the lens used for image making. Alternatively, cameras with TTL metering may meter directly through the diffuser attached to the taking lens. In both cases, the indicated exposure is reduced by 2 - 4 stops to place the pre-exposure on the desired shadow zone. This can be done by temporarily increasing the shutter speed or reducing the aperture. After the pre-exposure is made, the diffuser is removed and the camera's multiple-exposure device is enabled to allow for a double-exposure. Then, shutter speed or aperture is reset and the main image exposure is made on top of the pre-exposure.

## In Practice

The principal use of pre-exposure is not to improve shadow detail, since a simple increase in image-forming film exposure is the best way to do that. It is apparent from fig.3, however, that a pre-exposure reduces shadow contrast and, consequently, overall negative contrast. This is the clue to its principal application. Pre-exposure can enable a high-contrast scene to print normally on fixed-grade paper, and it is a method to reduce individual negative contrast on roll film. In addition, unlike the effect of reduced development or the use of lower-contrast paper, the midtone and highlight separation of a print, made from a pre-exposed negative, is unchanged.

Fig.4a-c show the same image, made from different negatives, but all prints were made on the same fixed-grade paper, while optimizing the highlight exposure. All negatives were given the same image exposure, determined by placing the pew-end on Zone I. However, the film exposures for fig.4b and 4c were preceded by a Zone-II and III exposure, respectively. The prints have an almost unchanged highlight and midtone appearance, but the shadows gradually lighten with increasing pre-exposure, and therefore, image detail seems to progressively extend into the lower print zones.

This definitely improved the image in fig.4b (Zone-II pre-exposure) as compared to fig.4a (no pre-exposure), but in fig.4c (Zone-III pre-exposure) the effect is overdone. The negative with a Zone-III pre-exposure has a fog level high enough to veil the shadow appearance at this print exposure setting. This might not be apparent on some images, but here, with large areas of uniform dark tone, it is noticeable and undesirable.

By way of comparison, a normal or high-contrast negative without pre-exposure may also be printed on variable-contrast paper, with its contrast setting lowered to lighten shadows and making detail more visible. This is similar to reducing film development for a high-contrast scene when dealing with graded papers. Fig.6 shows another example of printing the negative without pre-exposure, but this time, at a lower paper grade. Compared to fig.4a, made from the same negative, it has lighter shadows and we can see more detail; however, the highlight and midtone

fig.3 This graph illustrates the film characteristics for Fuji Neopan Acros 100, including Zone I, II and III pre-exposures, rated at EI 50 and given normal development in D-76 1+1. The pre-exposures add significantly to the negative shadow densities, while having little effect on midtone density and highlight densities. However, pre-exposure progressively increases the negative fog level and reduces shadow contrast, which despite increased shadow densities, gradually decreases film speed.

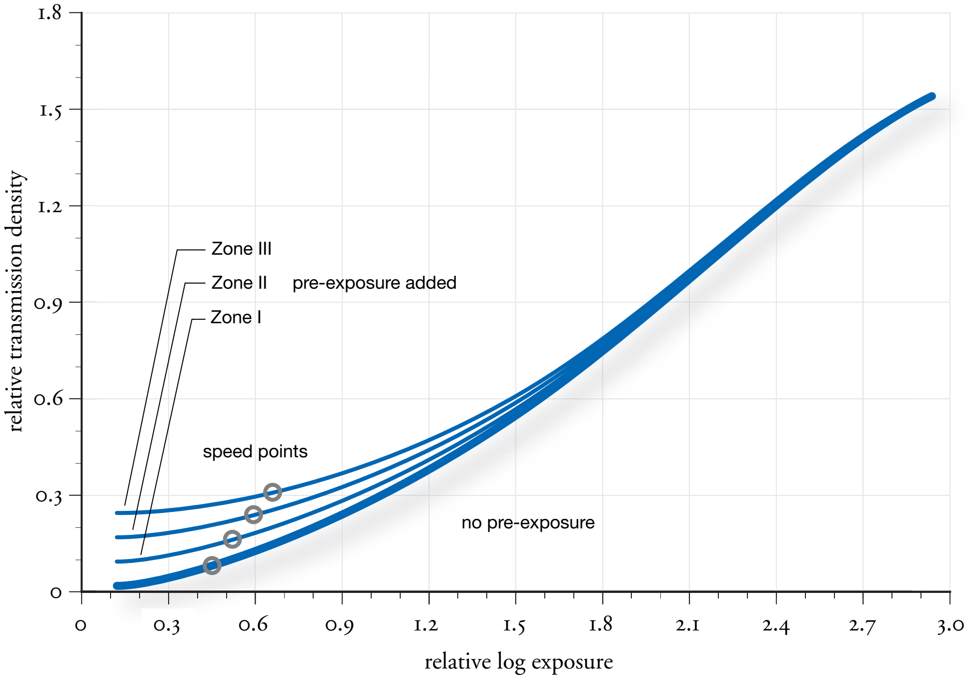
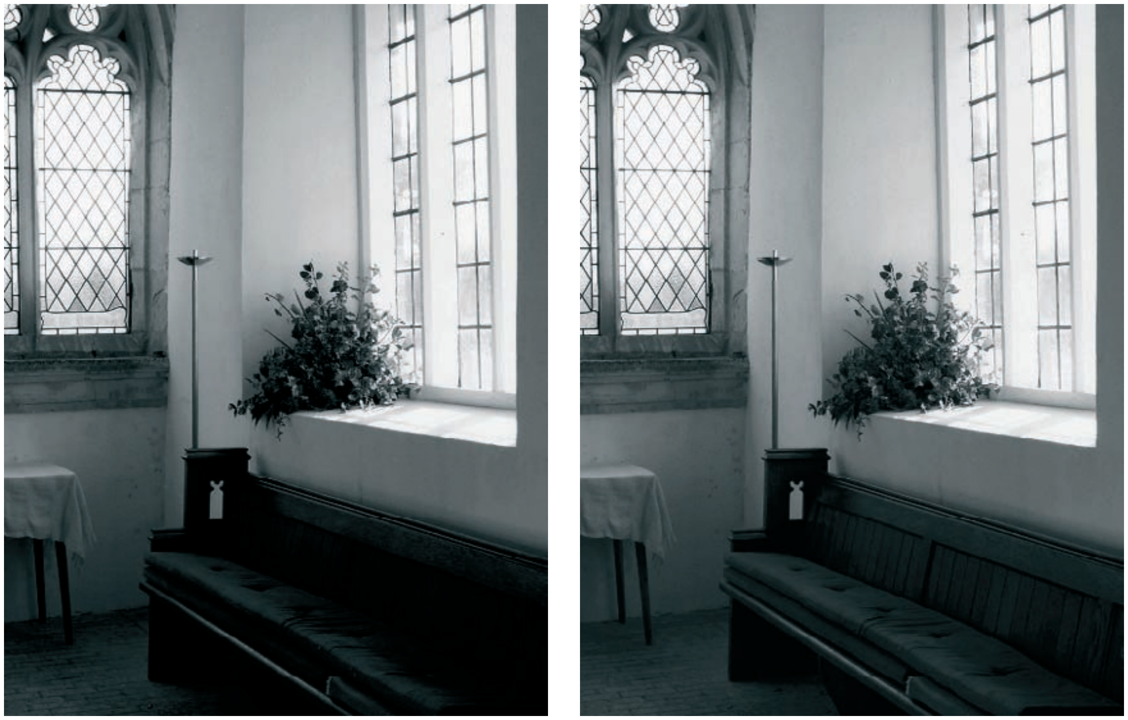


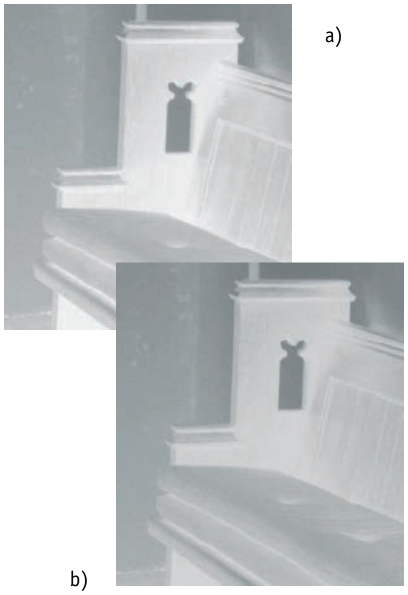
fig.4a-c This print sequence shows the effect of increasing film pre-exposure, when printed on fixed-grade paper with the exposure optimized for the highlights. From left to right, no pre-exposure, Zone II and III pre-exposure. Note how the shadows lose their luster in the print from the Zone-III pre-exposed film. It is easy to take pre-exposure too far.



a) no pre-exposure fixed-grade paper see fig.7 for tone reproduction

b) Zone-II pre-exposure fixed-grade paper see fig.8 for tone reproduction

fig.5a-b One claim, often made by the proponents of pre-exposure, is that the additional exposure takes the film beyond the threshold of density development and, therefore, adds additional shadow detail. A close-up of the negative's near-Zone-I shadow region, without (a) and with (b) pre-exposure, does not conclusively verify this claim, but the reduction of shadow contrast in (b) is obvious. Be that as it may, any additional deep-shadow detail is likely to be too dark for detection in the print anyway.



separation suffers. Compared to fig.4b or 4c, it shows greater shadow separation but, unfortunately, at the same expense. See fig.7, 8 and 9 to analyze and compare the tone reproduction of the prints shown in fig.4a, 4b and 6, respectively.

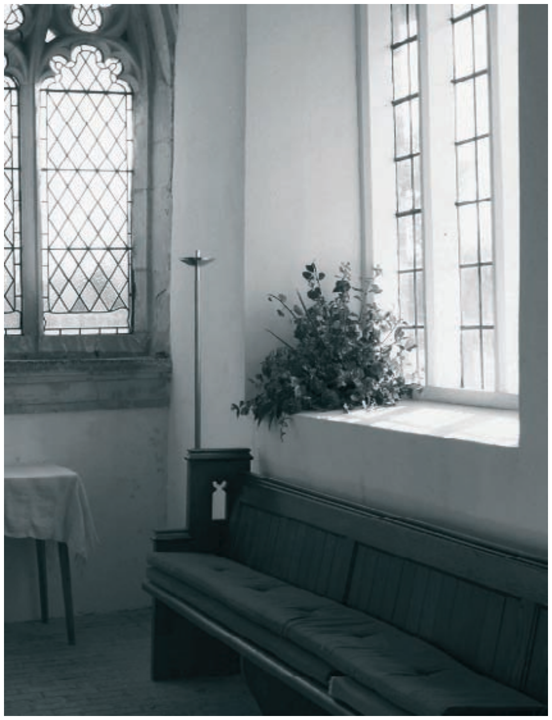
As a final alternative, one may be intrigued with printing a pre-exposed negative onto variable-contrast paper, with its contrast settings matched to the reduced negative density range. Unfortunately, this turns out to make little sense, as it does more harm than good. The reduced negative shadow contrast pushes most shadow detail onto very low print values, where it hides in the dark. A sample print of this is not featured here, but fig.10 shows the tone reproduction for verification and comparison.

In conclusion, the successful deployment of pre-exposure is wholly dependent upon the image content and is most effective when limited to fixed-grade papers. Combining film pre-exposure with variable-contrast printing is either not necessary, as fig.6 shows, or has potentially a negative effect, as fig.10 demonstrates. Since our brain is adept at spanning lighting extremes, it may not be easy to identify when pre-exposure will be beneficial. Reducing subject values to monochrome, by using a special viewing filter, will quickly improve tonal perception and exposure planning. However, only careful measurements with a spotmeter are likely to give trustworthy results.

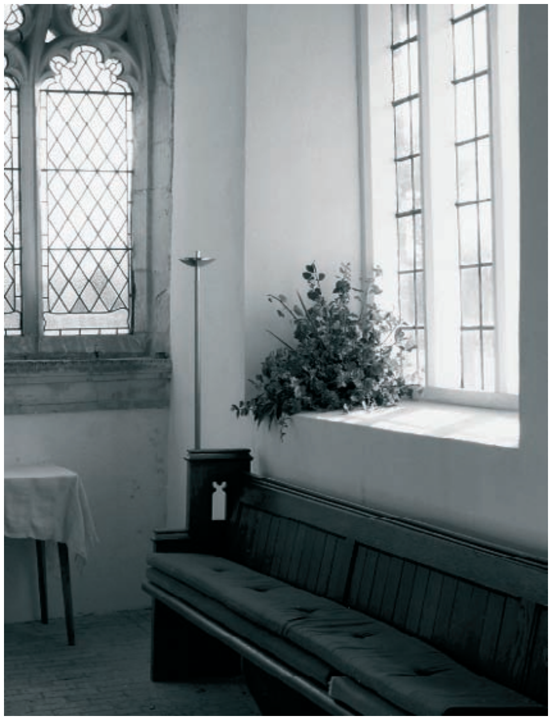
It is also worth comparing the effect of pre-exposure with that of print flashing, whose contrary effect reduces highlight separation and maintains shadow appearance. This is explained with examples in a separate chapter, called 'Print Flashing'.

## Further Variations

In this chapter, we have concerned ourselves with 'fogging' exposures made prior to the actual image exposure. The term 'fogging' refers to an exposure level that is higher than the film exposure threshold, whereas 'flashing' refers to a light level below that same threshold and does not, by itself, change negative density. Jacobson and Jacobson, in the chapter 'Increasing Film Speed' from their book *Developing*, suggest further variations on the theme of pre-exposure. These include changing the timing and intensity of the 'fogging' exposures to alter the apparent speed and reciprocity



c) Zone-III pre-exposure
fixed-grade paper



no pre-exposure
variable-contrast paper

see fig.9
for tone reproduction

fig.6 An alternative to pre-exposure is to print a normal or high-contrast negative without pre-exposure on variable-contrast paper, with its contrast setting lowered to lighten shadows and making detail more visible. Here the same negative as used for fig.4a was printed, but this time, at a lower paper grade. Compared to fig.4a, it has lighter shadows and we can see more detail, but only at the expense of reduced highlight and midtone separation. Compared to fig.4b or 4c, it shows greater shadow separation but, unfortunately, at the same expense.

characteristics of film. They define pre-treatment as hypersensitization and post-treatment as latensification. These treatments may be chemical or exposure-based and are not only of pictorial value, but also of practical value to those recording the extremely low-intensity objects encountered in astrophotography.

The authors suggest that light of a very low intensity is more effective at increasing an existing latent image than in overcoming the film's threshold for a new one. This indicates that post-exposure is more potent than pre-exposure. As part of Chris's preliminary investigation, these proposed variations were evaluated in two stages: first by evaluating the timing of the exposures and second, by evaluating the intensity of the 'fogging' exposure. In the first experiment, identical pre- and post-exposures were applied to an image using the same fogging intensity. The developed negatives were, for all practical purposes, identical and did not bear out the suggestion.

A second round of experimentation compared pre- and post-exposures using different light intensities. Jacobson and Jacobson recommend fogging the film, after the main exposure, to an extremely dim light in a darkened room, for a 30-minute duration. This is not a very practical proposition, since it is neither easy to establish or measure such a light intensity, nor is it pragmatic to expose film for 30 minutes, especially when battery-powered shutters are in use.

A final test, within the practical confines of available equipment, compared the effect of a brief high-intensity fogging-exposure (1/125 s) to a long low-intensity fogging exposure (8 s) of equal energy, but using two film types of very different reciprocity characteristics. The fogging exposures were tried both before and after the main exposure, to complete the analysis. The outcome showed some minor differences, not entirely explained by shutter tolerances and not consistent between the two films. This may be an interesting avenue for further research but is not of any particular value for image making. For further reading, we also recommend *The Theory of the Photographic Process* by Mees and James.

Consistency is important, and we recommended to preferably use the same aperture for the pre-exposure and the actual image exposure, since the outcome is in keeping with the theoretical sensitometry.

fig.7 This is the tone reproduction cycle for a normal negative, printed on normal fixed-grade paper. Note that the textural negative density range equals the textural paper log exposure range, and Zone-II shadows have typical densities of around 1.89.

no pre-exposure
fixed-grade paper

see fig.4a
for pictorial view

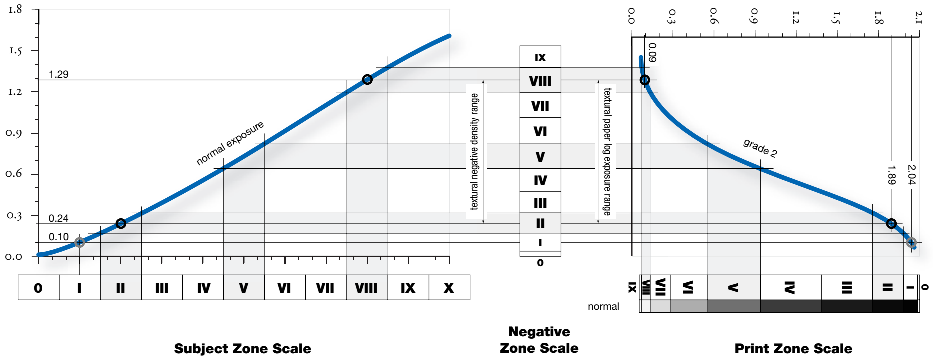


fig.8 This is the tone reproduction cycle for a Zone-II pre-exposed negative, printed on the same fixed-graded paper as in fig.7. Note that the upper portion of the paper characteristic curve is not utilized. The print has an almost unchanged highlight and midtone appearance, but shadows are lighter and have less contrast. However, lighter shadow detail is easier to see.

Zone-II
pre-exposure
fixed-grade paper

see fig.4b
for pictorial view

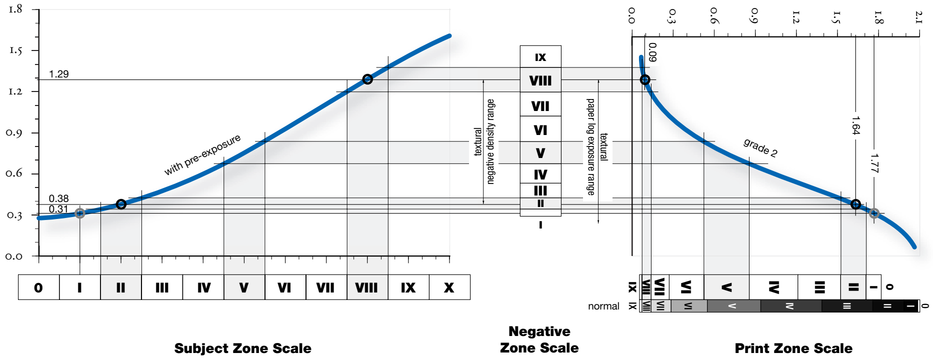


fig.9 This is the tone reproduction cycle for a normal negative, printed on a lower paper contrast to match Zone-II shadows densities with fig.8. Compared to fig.7, it has lighter shadows and we can see more detail, but only at the expense of reduced highlight and midtone separation. Compared to fig.8, it shows greater shadow separation but, unfortunately, at the same expense.

no pre-exposure
VC paper

see fig.6
for pictorial view

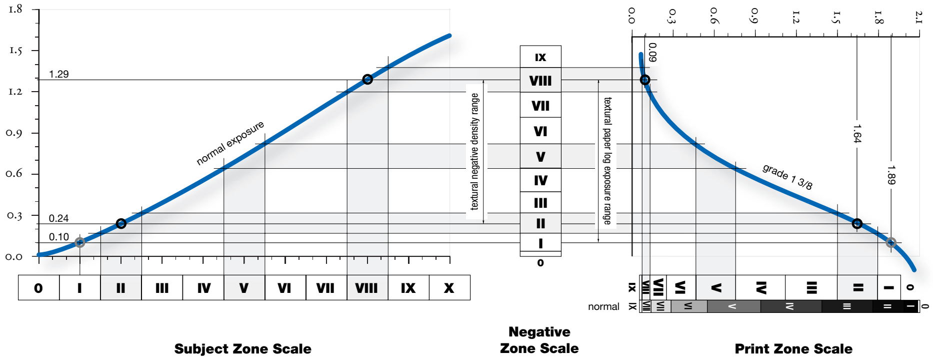
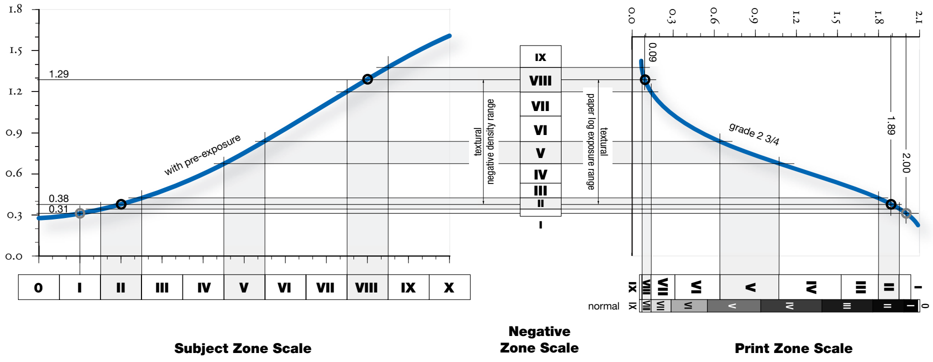


fig.10 This is the tone reproduction cycle for a pre-exposed negative, printed on variable-contrast paper, to accurately match the reduced negative density range. However, doing so makes little sense. The reduced shadow contrast of the negative pushes most shadow detail onto very low print values, beyond human detection. The whole print will be too dark.

Zone-II
pre-exposure
VC paper



# Applied Zone System

## Contrast Control with development or paper grades?

Zone System basics are easy to understand, but mastery comes only with a full comprehension of its role within the complete photographic process. It is important to realize that the Zone System is not an exclusive technique but only a building block for a quality print. It does not replace other darkroom techniques but promotes them from rescue operations to fine-tuning tools. The Zone System ensures a good negative as a starting point, because it is important to have plenty of detail in shadows and highlights. Nevertheless, only additional printing techniques turn a good print into a fine print. I recommend the Zone System to control overall negative contrast and to fine-tune local image contrast during printing, as demonstrated in the following examples.

### Local and Overall Contrast

Global or overall contrast is the difference in brightness between the lightest and darkest areas of a subject, negative, image or print. Local contrast refers to the brightness difference within a restricted area. Fig.1 is an image of modest overall contrast between an illuminated wall on the right and the wall in shadow, but the local contrast for each wall is rather low.

Figures 2a&b are two prints of a high overall contrast scene, made from the same negative and both printed on grade-2 paper. The subject brightness range between the sunlit window and the shaded dark wood in the foreground (overall contrast) was more than the film could handle with normal development. Nevertheless, the brightness ranges within the windows and within the interior of the room (two local contrast areas) were actually low. Fig.2a was printed

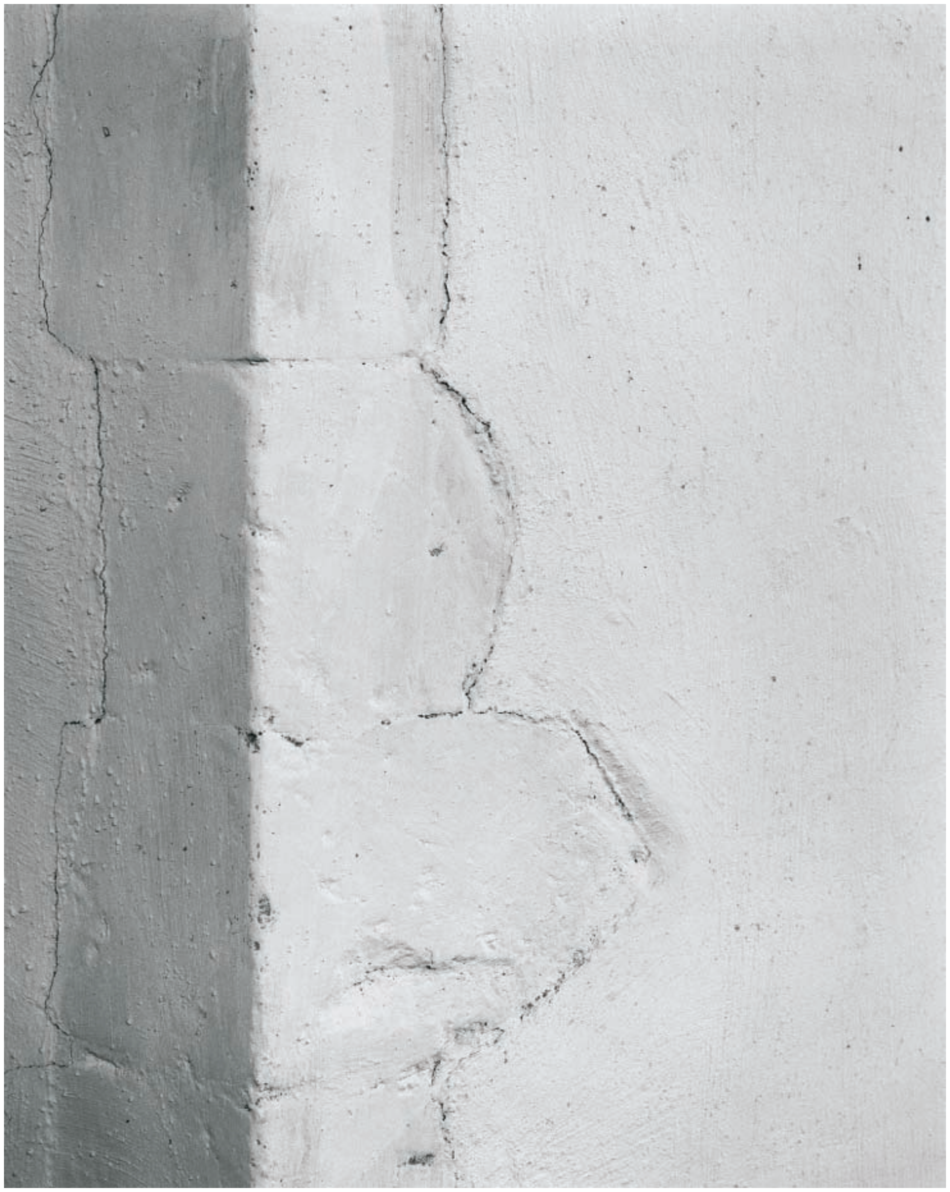


fig.1 This image has a modest overall contrast between the illuminated wall on the right and the wall in shadow, but the local contrast for each wall is rather low.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50030-2

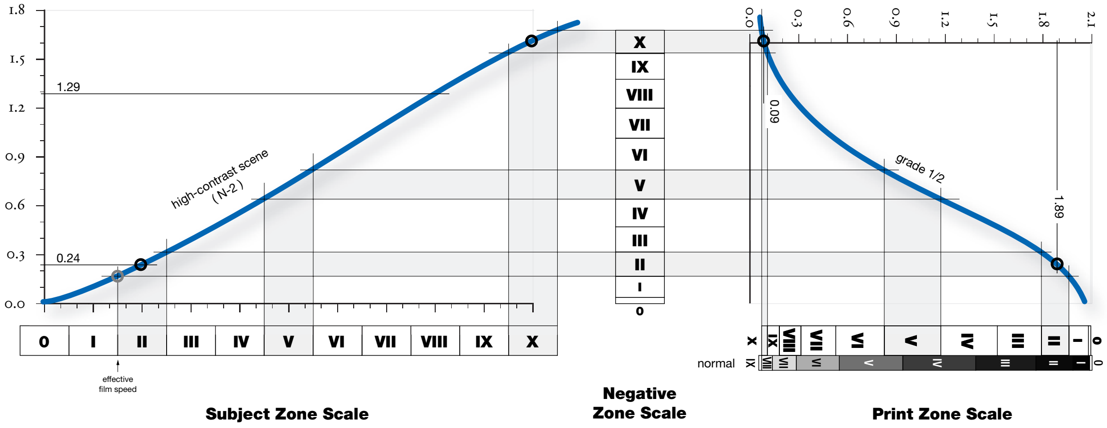
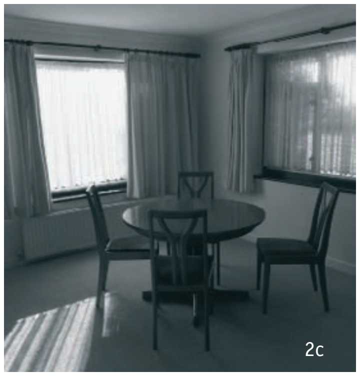
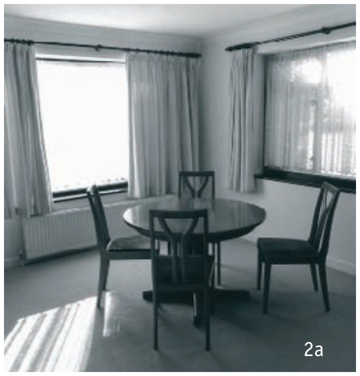
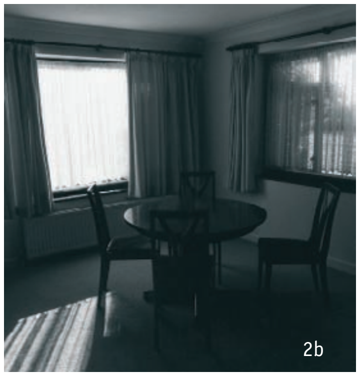


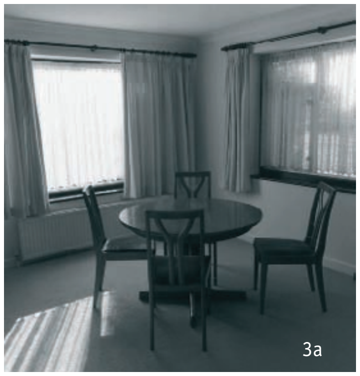
fig.2 (left) A high-contrast scene combined with normal film development creates dense negative highlights, but a soft grade-0.5 paper is used to salvage the image (fig.2c).

fig.3a (bottom) New negative with reduced film development (N-2) and printed on grade-2 paper, as shown in fig.3. Highlight and shadow detail are maintained similar to the soft paper grade in fig.2c, but again, at the expense of local contrast.









paper-grade adjusted

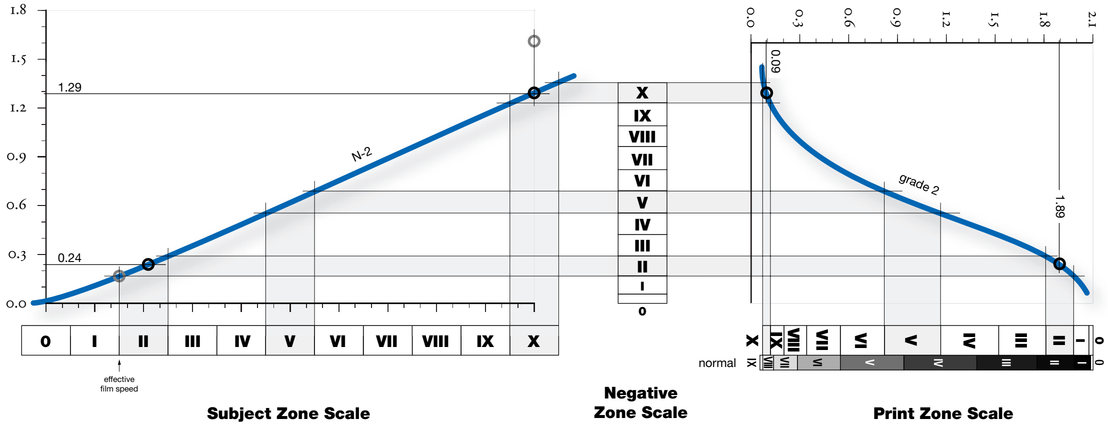
high-contrast scene
normal film development & paper grade
(exposed for the shadows)

high-contrast scene
normal film development & paper grade
(exposed for the highlights)

film-development adjusted

fig.2c (top) Same negative as for figures 2a&b but printed with grade-0.5 filtration, as shown in fig.2. Highlight and shadow detail are maintained at the expense of local contrast.

fig.3 (right) An intentional film underdevelopment extends the subject brightness range and creates negative highlight densities printable on normal paper (fig.3a).



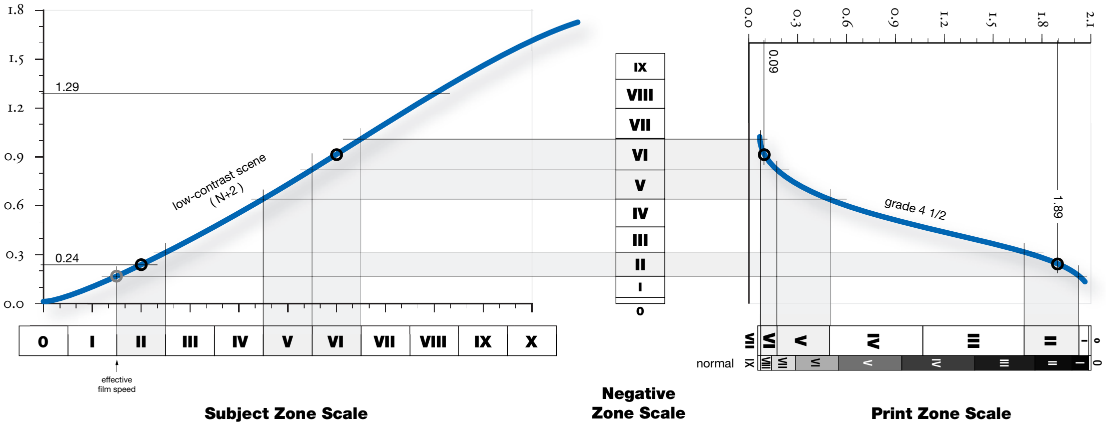
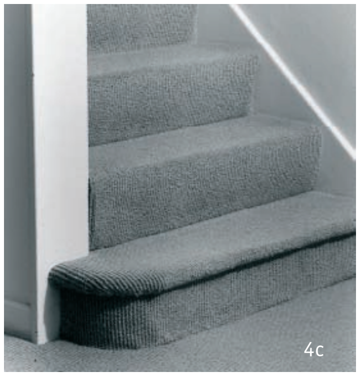
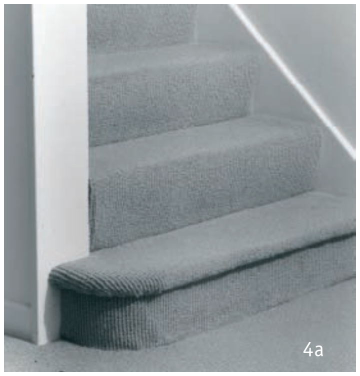


fig.4 (left) A low-contrast scene combined with normal film development creates weak negative highlights, but a hard grade-4.5 paper is used to make a good print (fig.4c).

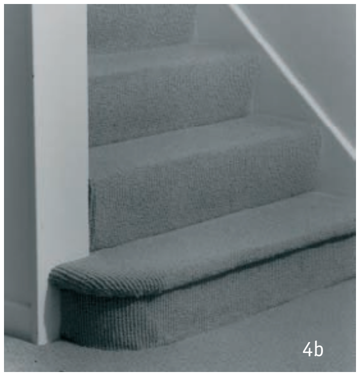
fig.5a (bottom) New negative with extended film development (N+2) and printed on grade-2 paper, as shown in fig.5. Highlight and shadow detail are maintained similar to the hard paper grade in fig.4c.



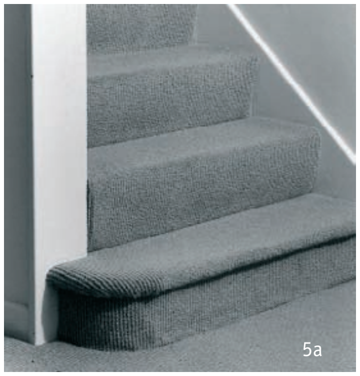
paper-grade adjusted



low-contrast scene
normal film development & paper grade
(exposed for the highlights)



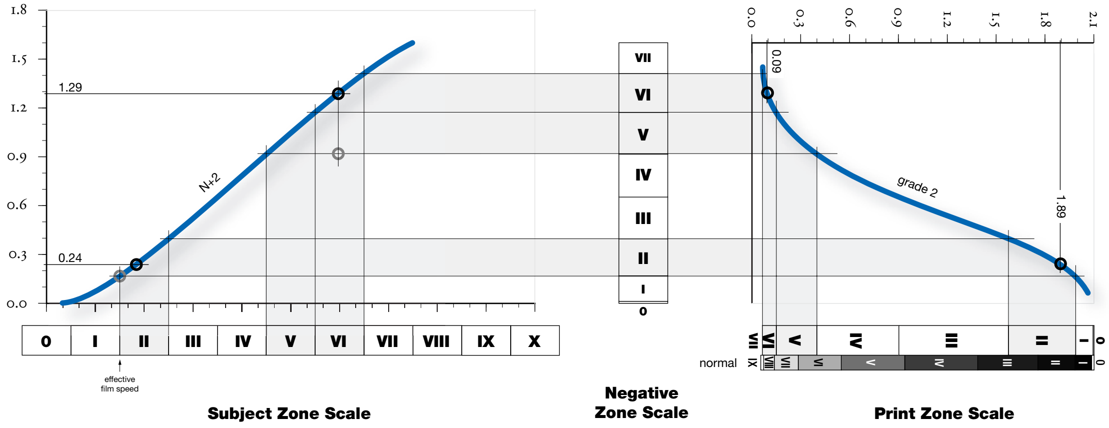
low-contrast scene
normal film development & paper grade
(exposed for the shadows)



film-development adjusted

fig.4c (top) Same negative as for figures 4a&b but printed with grade-4.5 filtration, as shown in fig.4. Highlight and shadow detail are maintained with increased local and overall contrast.

fig.5 (right) An intentional film overdevelopment increases the negative density range and improves highlight densities, to print well on normal-grade paper (fig.5a).



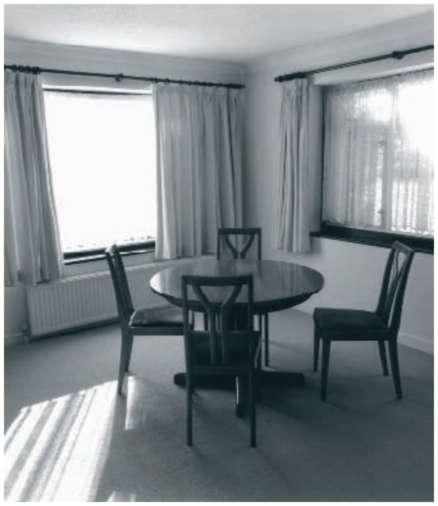


fig.6a The same negative as for fig.6a and printed on the same paper grade, but exposed to optimize the shadow detail. In this case, most highlight detail is lost.

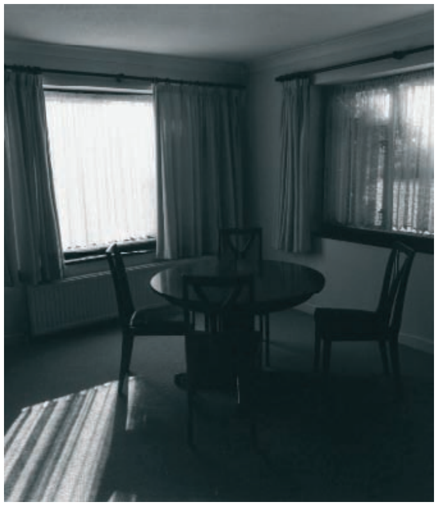


fig.6b High contrast scene, normal film development and printed on grade-2 paper. The print was exposed to optimize the highlight detail, but most shadow detail is lost.

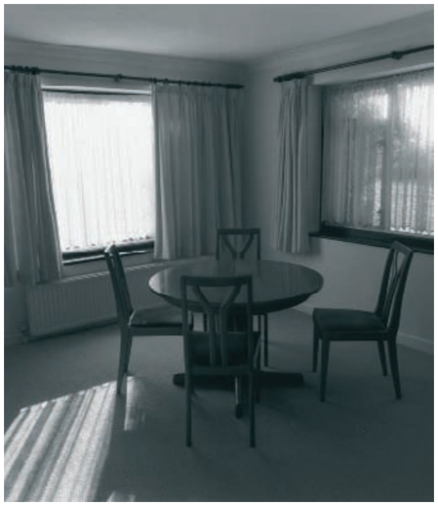


fig.6c Same negative as for figures 6a&b but printed with grade-0.5 filtration. Highlight and shadow detail are maintained at the expense of local contrast.

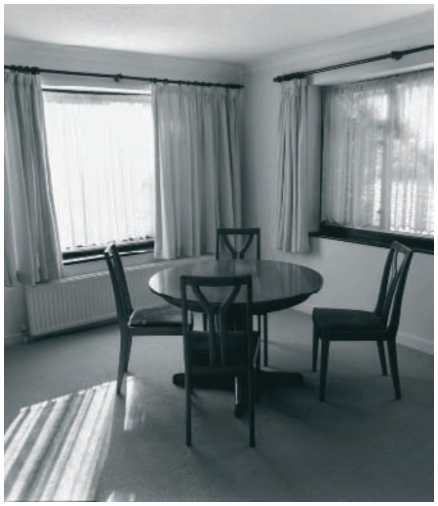


fig.6d Same negative as for figures 6a&b, but print received the base exposure of fig.6b, and the highlights received an additional burn-in exposure to show the same detail as fig.6a.

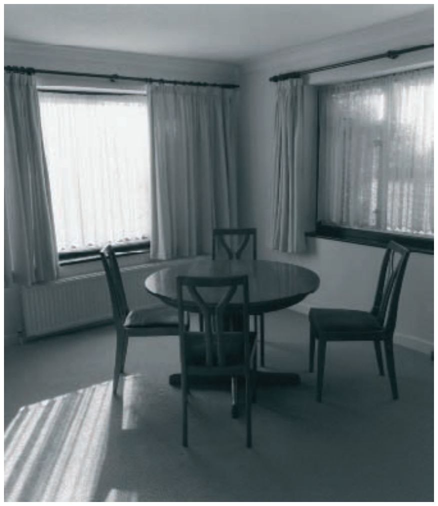


fig.7 New negative with reduced film development (N-2) and printed on grade-2 paper. Highlight and shadow detail are maintained similar to fig.6c, again at the expense of local contrast.

with the exposure optimized for the shadows to reveal detail in the room's interior. Fig.2b was printed with optimized highlight exposure to reveal detail in the windows. Neither print is satisfactory, because either shadow or highlight detail is clipped and lost, but together they clearly reveal that the necessary negative detail is available to make a good print.

Figures 4a&b are two prints of a low-contrast scene, made from the same negative and both printed on a grade-2 paper. The overall subject brightness range between the bright wall and the shadow below the bottom stair is too low for normal film development. Fig.4a was printed with the exposure optimized for the highlight detail on the wall. Fig.4b was printed with optimized shadow exposure. Neither print is satisfactory, because they capture all negative detail available but are too soft to make for a realistic-looking print. We have a few techniques at our disposal to unlock the detail in figures 2a&b and improve the contrast in figures 4a&b.

### Adjusting Print Contrast

A normal-contrast negative prints well on grade-2 paper. If the contrast is above normal, as in figures 2a&b, a softer paper grade rescues the print. This was done to produce the print in fig.2c, using a soft grade-0.5 filtration. Otherwise, it is a 'straight print', meaning no print manipulation such as dodging & burning was applied. The print shows all highlight and shadow detail, but at a terrible cost to local contrast. The interior of the room appears flat, gloomy and unattractive.

If the negative has a below-normal contrast, as in figures 4a&b, a harder paper grade is used to compensate for it. This was done to produce the print in fig.4c, using a hard grade-4.5 filtration. Otherwise, it is a straight print without any dodging & burning. The print has greatly benefited from increased overall and local contrast and looks far more realistic now.

### Adjusting Film Development

The main purpose of the Zone System is to optimize film exposure and overall negative contrast. To create the print in fig.3a, an additional negative was prepared, placing the interior shadows on Zone III and reducing the film development to N-2 to control the highlights in the window. This captures the entire subject brightness range, and the negative printed well on grade-2 paper, maintaining highlight and shadow detail but, similarly to the print in fig.2c, at the expense of local contrast. Using paper-grade or film-development adjustments in order to harness high overall-contrast scenes with normal or low local contrast does not deliver attractive results.

To create the print in fig.5a, an additional negative was prepared, placing the shadow below the bottom stair on Zone III and increasing the film development to N+2 to raise the tonality on the white wall. This increased the negative density range to normal, and the negative printed well on grade-2 paper. Similar to the print in fig.4c, the print in fig.5a greatly benefitted from an increase in negative contrast. Using paper-grade or film-development adjustments in order to compensate for a lack in overall subject contrast works well and delivers attractive results.

### Dodging & Burning

Unfortunately, dodging & burning are often considered to be nothing more than salvaging techniques for a less than perfect negative, but they are really invaluable print controls. Most of Ansel Adams' gorgeous prints were brought to perfection through heavy manipulation with dodging & burning. This technique maintains or adds local contrast, while bringing forward the otherwise missing detail to selected shadows and highlights. In fig.6d, the advantages of the prints in figures 6a&b are combined. Using the same negative and paper contrast, this print received one overall exposure to show shadow detail as in fig.6a, and the highlights received an additional burn-in exposure through a custom mask (not shown) to reveal the same detail as in fig.6b. For comparison, the already failed attempts to control the high overall contrast of this scene through paper-grade adjustment (see fig.6c) or film-development adjustment (see fig.7) are also shown.

## Contrast Control Techniques Compared

From statements made over the decades, it seems that you can only use one contrast control technique at a time. Statements such as "The Zone System eliminates the need for dodging & burning" or "Variable Contrast papers have eliminated the need for the Zone System" seem to persist in spite of evidence to the contrary. Alone, neither one of these techniques is an optimum solution, but a careful combination of them will create the best possible print.

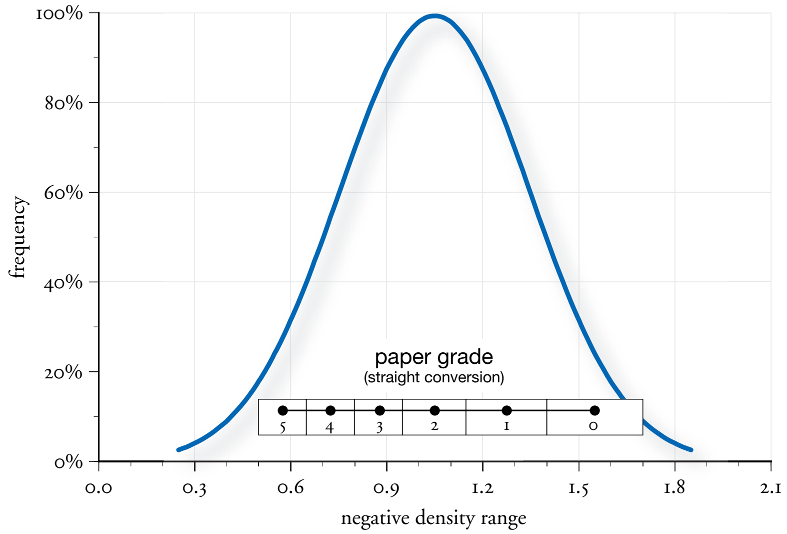


fig.8 The evaluation of over 1,000 amateur negatives reveals the normal distribution of negative density ranges. The average amateur negative has a density range of 1.05 and, consequently, prints well on a grade-2 paper. Few negatives are outside the paper's capability and end up with clipped highlights or shadows, but marginal negatives leave little room for creative manipulation.

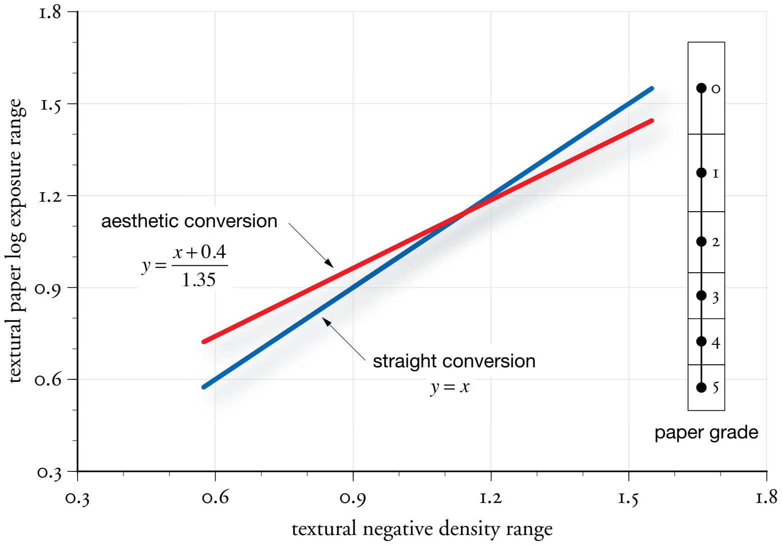


fig.9 Empirical data shows that hard negatives print better on harder paper than expected, and soft negatives benefit from softer paper than expected. This is reflected through the equation of aesthetic conversion, but its application makes for softer prints than typically found in the amateur field.

As shown in figures 2 through 5, there is indeed little difference between a paper-contrast adjustment and film-development adjustment. In a straight print, both achieve very similar results in very different ways. If negative or paper contrast is adjusted appropriately, a straight print captures the entire overall contrast with either technique, and prints with matching highlights and shadows can be made. All other tones are controlled by the interaction of the individual film and paper characteristic curves (image gradation). However, negative or paper-contrast adjustments alone only work well for low contrast scenes. High-contrasts scenes usually suffer from unattractive local contrast after such treatment.

Consequently, high-contrast scenes ought to be controlled with adjustments in film development or paper contrast up to a point, but the examples in figures 6 and 7 show that high overall contrast, combined with normal or low local contrast, is best controlled with dodging & burning. Fig.6d, where this was done, is the best print of the group. Use the Zone System and film-development adjustments to control extreme contrast situation, but avoid over-reduction of normal or low local contrast. This will allow for a straight print, but it will also be a dull print.

A straight print is rarely the aim anyway, because it seldom creates a fine print. A straight print of a high-contrast scene will always suffer from lack of tonal separation due to tonal compression. This problem can be better fixed with dodging & burning. In some cases, however, it does make sense to create a fully contrast-adjusted negative first. If dodging & burning is applied to such a negative, the entire spectrum of softer and harder paper grades are available to control local contrast. This is a flexibility not available if a paper-contrast adjustment was already needed to compensate for a less than perfect negative.

## From Negative Density Range to Paper Grade

Fig.8 illustrates the results of an evaluation of over 1,000 amateur negatives, which reveals the normal distribution of negative density ranges. The average amateur negative has a density range of 1.05 and, consequently, prints well on a grade-2 paper. Few negatives are outside the paper's capability and end up with clipped highlights or shadows, but marginal negatives leave little room for creative manipulation.

In 'Tone Reproduction', we illustrated how the textural negative density range turns into the textural paper log exposure range when the negative is projected onto the paper. It is well known that a negative with a short density range must be printed on a positive material with a short exposure range and vice versa. Since density and exposure range are both measured in log units, we logically assumed a straight conversion. A 0.3 change in negative density simply requires a 0.3 change in paper log exposure. In 'Measuring Paper Contrast', we will show how textural paper exposure ranges are grouped into paper grades. Consequently, we found a straight conversion from negative density ranges to paper grades and followed it through the rest of the book. However, there is a another way of looking at this conversion.

In 1947 T. D. Sanders found an interesting empirical relationship between approximately 3,000 prints made from 170 negatives during Loyd A. Jones and H. R. Condit's 1941 study. The analysis of the statistical print judgment from 30 independent observers revealed that for maximum print quality a surprising rule had to be followed. For soft papers, the density range of the negatives exceeded the log exposure range of the paper, while for hard papers, the negative density range was smaller than the paper exposure range. In other words, hard negatives printed better on slightly harder paper than expected, and soft negatives did benefit from slightly softer paper than expected. Fig.9 shows this empirical relationship graphically.

It should be mentioned that prints following this relationship are somewhat softer than typically found in the amateur field, but were, in the opinion of the 30 observers, of superior photographic quality. You may try both, the straight and the aesthetic negative density range conversion, to find a matching paper grade and judge for yourself.

## Final Thoughts about Successful Contrast Control

From my own work, I can make the following recommendations. Use the Zone System to determine adequate shadow exposure, and adjust negative contrast through development. Watch for local and overall contrast, and do not try to cover the entire subject brightness range in high-contrast scenes. A careful practitioner visualizes important shadow, highlight and mid-tones of the scene and realizes that isolated highlight extremes are better burned-in at the printing stage. Dodging and burning are valuable print controls, not rescue operations. A straight print is rarely a fine print. In most cases, reserve paper-grade changes for creative image manipulation. Choosing a different grade of paper can also be used to salvage a less than perfect negative especially in low-contrast scenes, but the Zone System creates a better negative and provides more print flexibility. VC papers allow for additional creativity, adjusting local print contrast to add impact and emphasis. However, the combination of paper grades, Zone System and dodging & burning can handle subject brightness conditions none of these can handle on its own.

Compensating for subject contrast through film development is very similar to compensating for negative contrast with variable-contrast (VC) papers. This does not mean that VC papers have replaced the Zone System altogether. The Zone System delivers a perfect negative, and VC papers are very tolerant of less than perfect negatives. But, when used to get the most out of a mediocre negative, VC papers leave less room to adjust for local image-contrast needs. However, when used together, Zone System and variable-contrast papers provide more creative flexibility than either one possibly could alone. For a fine-art printer, this is not an either/or decision. Both are powerful tools in their own right.

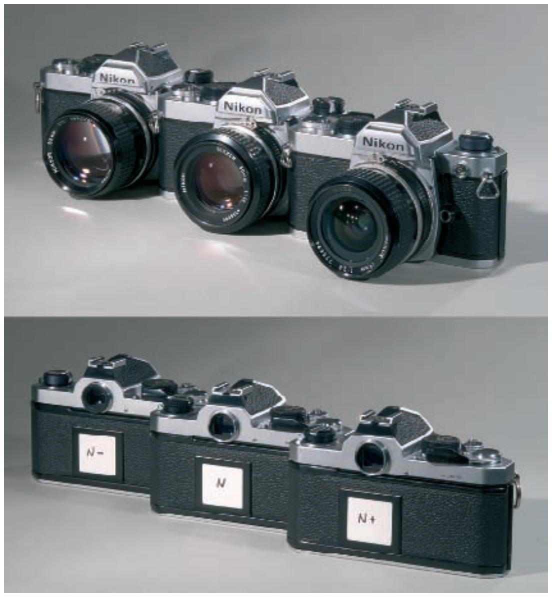
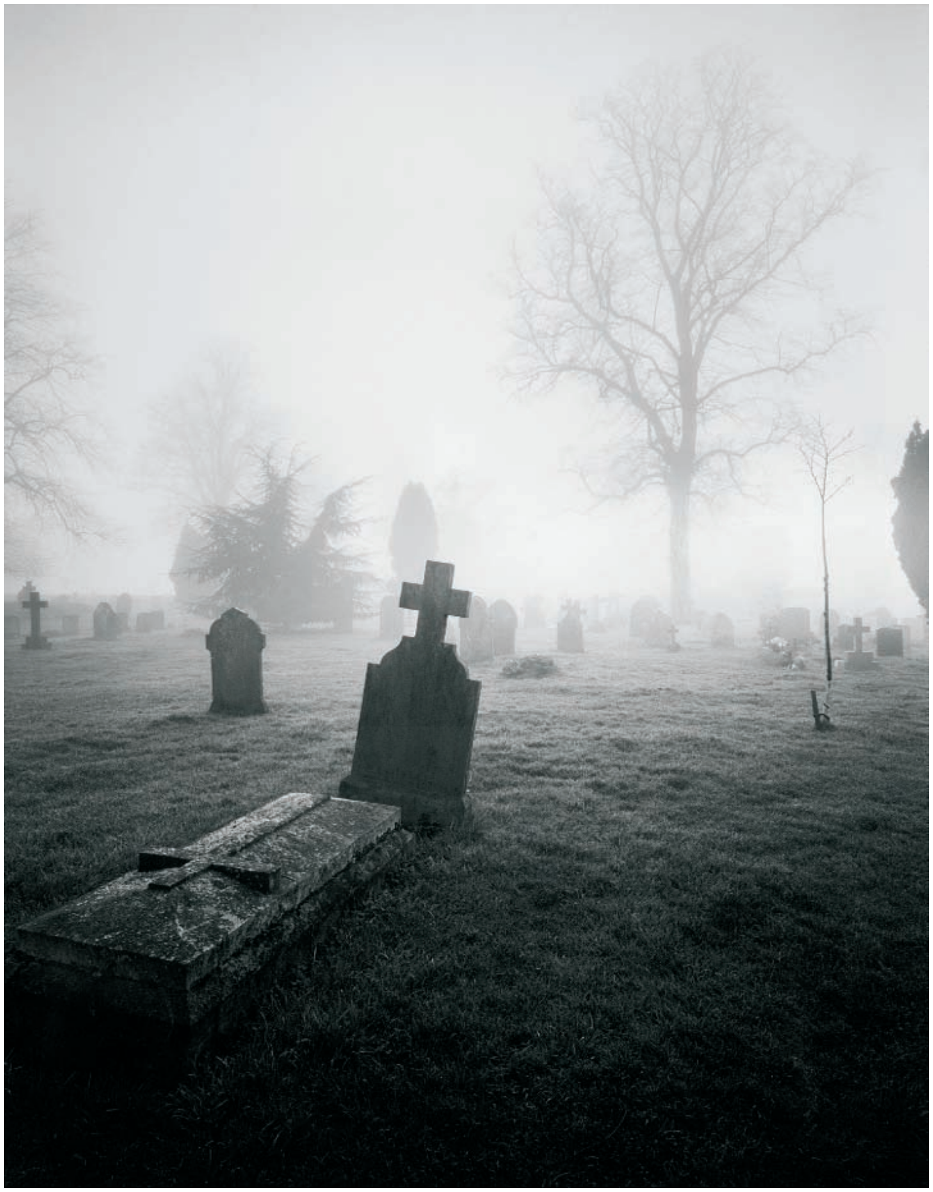


fig.10 It is often thought that 35mm photographers cannot benefit from the Zone System, because 35mm cameras do not have the flexibility of replaceable film backs. But, most mechanical 35mm camera bodies cost less than a medium-format film back. Here, three bodies are labeled for N-, N and N+ development. This way, exposures are 'collected' separately until each roll of film can be developed independently.

# C41 Zone System

## Contrast control with chromogenic monochrome films



There is a dark horse among the arsenal of currently available monochrome films. Chromogenic monochrome films were developed mainly to exploit the mainstream availability of C41 color processing and make monochrome imaging available to all photographers, but some of these films also produce excellent images on conventional B&W paper and also offer several other important advantages.

Since reliable C41 development is widely available throughout the world, it gives the travelling photographer the assurance of passing developed film through airport X-ray machines without the risk of ruining exposed emulsions. Chromogenic B&W films provide an extremely wide latitude towards overexposure and have a negative density characteristic that gently rolls off extreme highlights. This makes these films ideal for high-contrast situations. A chromogenic image is formed by dyes rather than metallic silver, which offers a softer grain and produces images with creamy highlights. The dyes are the reason why chromogenic films are much easier to scan than silver-based films, even at high resolutions. However, many photographers shun chromogenic B&W films for the apparent lack of contrast control during standard C41 processing and archival concerns.

This chapter addresses both concerns by exploring the capability of customized C41 development to accommodate the scene contrast, just as one would with the traditional Zone System, and by clarifying the archival properties of chromogenic materials.

fig.1 Ilford XP2 is capable of very beautiful effects especially in high-contrast conditions, in this case staring into a glaring misty sunrise. Mamiya 7, 43mm f/16, printed on Agfa Multicontrast Classic with filter 4 for the foreground and filter 0 for the sky.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50031-4

My favorite chromogenic B&W film is Ilford's XP2 Super, which I mainly use for landscape photography, especially when travelling light with my Mamiya 7. Since I do my own C41 film development using a standard C41 development kit and a Jobo CPE processor, I'm able to control chromogenic negative contrast very similarly to B&W negative contrast.

## Faded Memories

Since color film technology is not considered elsewhere in this book, it is prudent to address the thorny subject of longevity first. All statements about longevity are predictions, mostly based on the outcome of accelerated fade tests under extreme environmental conditions. The acceptance criteria, as well as the test conditions, vary. For instance, claims about the lifetime of inkjet prints often refer to the point where the print has an 'unacceptable' appearance. That gives a wide scope for interpretation. However, with negatives, the degradation is easier to define and counteract. Unlike color prints, fading can be measured objectively with a transmission densitometer. Indeed, a common industry standard is to measure the storage time required to reduce a negative density of 1.0 by 0.1. This fading is approximately proportional to the negative density range, so in this case, the negative would require printing with an extra 1/2-grade contrast setting to recover the loss of negative density.

Chromogenic B&W films use color film technology based on three separate layers made from cyan, yellow and magenta dyes. Each dye layer has a different fading speed, cyan fading first and magenta being most stable. Fortunately, cyan has little effect with monochrome printing, so the significant image forming dyes are yellow and magenta. Manufacturers' predictions estimate that the yellow and magenta dyes fade respectively over a range of 20-50 years and 50-100 years, by the amount described above, under typical ambient conditions. These predictions are made from accelerated tests, which are run at high temperatures, and as such, are likely to be pessimistic, since high temperatures also simulate other degradation mechanisms. The common dark storage condition for negatives, within paper or plastic sleeves, will contribute to a longer life.

Fortunately, because the negative is not the final image, a proportional density loss can be remedied by printing an old negative with a higher paper contrast to recover the tonal range. Over the same span of time, our paper supplies will change, probably forcing the printer to reprint an old negative from scratch anyway. In the case of negative scanning, the image adjustment controls in the scanning software will correct the defect. In fact, some manufacturers indicate that the useful life of a chromogenic B&W negative may well exceed that of the acetate base, which is of course used with silver-based roll films too.

To be realistic, many of us are not going to be around long enough to find out if these predictions are wrong. In all probability, I am less likely to have a problem with a treasured negative taken today on chromogenic film in my retirement darkroom than suffer the effects of poorly fixed or washed silver images. In today's digital climate, more concern should be levied over the choice, availability and improvement of monochrome films, developers and papers over the next 10 years. This does not mean that we should not do whatever we can to protect our negatives against premature deterioration. As you would with silver-based negatives and prints, store chromogenic negatives in acid-free sleeves, at or below 20°C and between 30-50% relative humidity, and avoid unnecessary exposure to light.

## Film Choice

This chapter investigates Ilford's XP2 Super, which is similar to Fuji's Neopan 400CN. Kodak's T400CN was also evaluated in combination with variable contrast paper, but, in common with a number of users, the negatives did not print as predicted, from the measured baseboard intensity and contrast. The prints were about 1.5 grades softer than expected and about 1 stop underexposed. I concluded that the orange base and brown image reduced the amount of blue 'hard' light passing through the negative, altering the print contrast and exposure setting. Judging from the advertising campaign that Kodak uses, and the appearance of the negatives, I assume that T400CN is ideally suited for accurate color control with color print processing methods.

## C41 Processing

At the time of writing, my local lab charges the same to develop a roll of C41 as it costs me to buy it. Push or pull development costs more. If several films are developed at once, home processing can be more fig.2 This table provides C41 processing times for alternative temperatures.

| °C | °F | preheat | develop (10% / °C) | stop | bleach | wash |
|---|---|---|---|---|---|---|
| **40** | 104 | 5:00 | 2:40 | 0:30 | 4:00 | 6:00 |
| **39** | 102 | | 2:55 | | | |
| **38** | 100 | | 3:15 | | | |
| **37** | 99 | | 3:35 | | | |
| **36** | 97 | | 4:00 | | | |
| **35** | 95 | | 4:25 | | | |
| **34** | 93 | | 4:50 | | | |
| **33** | 91 | | 5:20 | | | |
| **32** | 90 | | 5:55 | | | |

fig.3 To maintain consistent results, some processing-time adjustments are required when developing additional films.

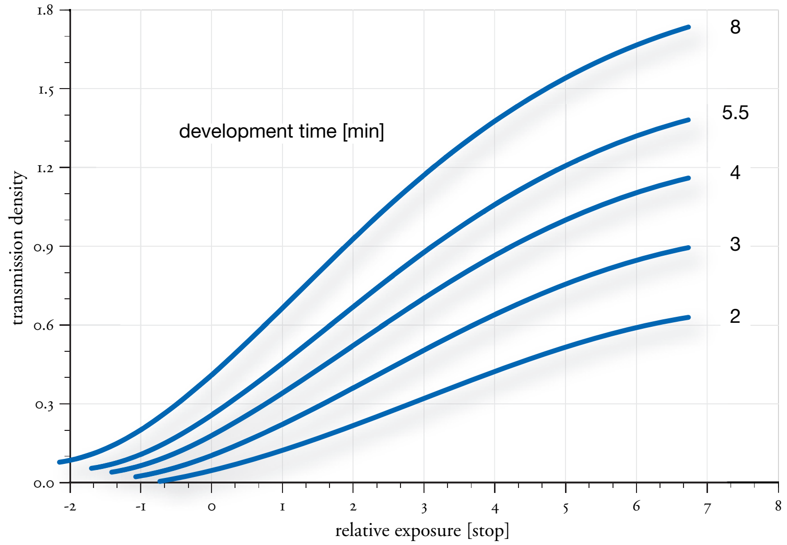
| film | developer | bleach |
|---|---|---|
| 1 | - | - |
| 2 | + 5% | + 20% |
| 3 | + 11% | + 30% |

convenient and cost effective, at about 1/4 of the price. The main consideration with home processing C41 films is to find a reliable method to keep the chemicals and developing tank at 38°C, and agitate evenly. The standard processing steps are:

1. preheat
2. develop
3. stop bath or rinse
4. bleach fix and wash

They are followed by an optional stabilization. All steps require continuous or frequent agitation. The two choices with C41 chemistry are to replenish or to replace. Small volume (300 ml) 'press packs' are commonly available and can process six films with ease, depending on the level of developer oxidation. Films are best developed in pairs, each subsequent pair requiring an adjustment in processing time, to allow for the reduction in chemical activity. Even with non-replenishment chemistry, developer and bleach-fix solutions are reused several times, with an appropriate extension of processing times. Most instructions recommend 5% additional development for each subsequent film, up to a given film limit.

fig.4 These are the characteristic curves for Ilford XP2 developed in a Jobo CPE-2 processor at 38°C in fresh chemistry.



Replenishment systems use a larger working volume, and use a dedicated replenisher to maintain developer and bleach fix activity. This approach is economical with high throughput, and is a way of keeping constant developing times and conditions. The replenisher approach may be more appropriate for film processors that do not over-agitate during the development cycle.

With non-replenishment chemistry, films should be processed in quick succession, otherwise the chemical activity of the working solution rapidly reduces. After developing two films, I developed another a few days later. The working solutions had been stored in their bottles with a squirt of protective spray. Even so, the image on the third film was barely visible. After some enquiry, I realized that the rotary form of agitation that takes place inside the Jobo tank introduces oxygen into the developer solution. With time, this dissolved oxygen oxidizes the active ingredients. In addition, the excellent volume efficiency of horizontal rotation (only 300 ml for two films) is another reason for 'perceived' developer droop, in the same way as film processing in highly dilute developers.

Hence, for maximum capacity and consistency, my advice is to use 100 ml at a time, creating 300 ml of working solution at the customary 1+2 dilution. Develop two films at a time, up to a maximum of four films, and then discard within 48 hours.

An ideal film home-processor, for use with replenishment chemistry, would have a large volume of developer solution, a vertical axis of rotation and complete full-time film immersion. This would stir in less oxygen, and so, prolong developer life.

## Agitation

The processing times for C41 are relatively short. But, with monochrome film processing in an inversion tank, anything under 4 minutes is normally not recommended. With C41 development, careful agitation is required to avoid streaking. The normal inversion and twist inversion technique, that serves so well with conventional monochrome films, can give problems with C41. With just 300 ml of chemistry in a hand tank, excessive frothing of the developer from repeated inversions can cause processing marks along the upper film edge. As the volume of the active chemistry reduces with each use, potential for partial film immersion increases. In addition, the repeated removal of the tank from its water bath cools the tank quickly. Fortunately, the Jobo unit controls both temperature and agitation. The spiral tank is held on its side within the water bath and rotated back and forth, without causing developer frothing. This not only keeps 'fresh' developer over the surface of the film, but also enables 300 ml of chemicals to process two 120 or 135 films at a time. The original Jobo film tank (4312) does not empty particularly neatly or quickly, whereas in comparison, the latest film tank (1520) and spirals empty and fill well. In addition, the new reels have less friction enabling film to be pushed onto the reel in a matter of seconds, without endless shuffling.

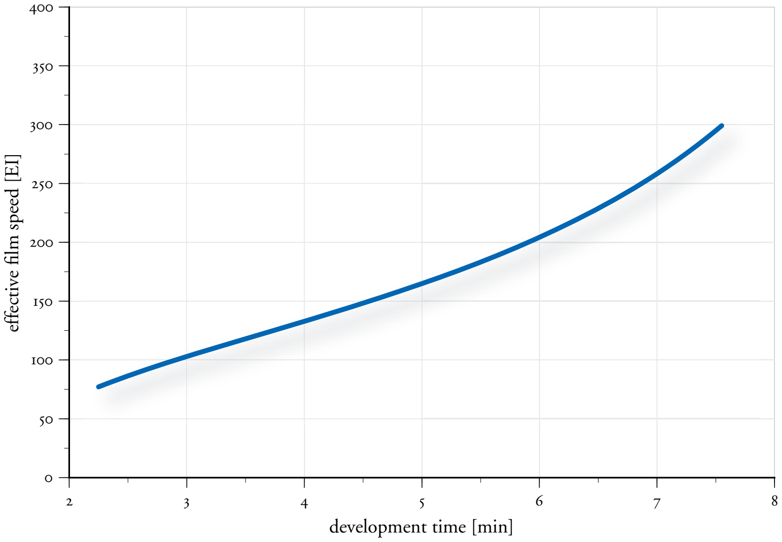


fig.5 Ilford XP2 effective film speed or exposure index (EI) versus development time

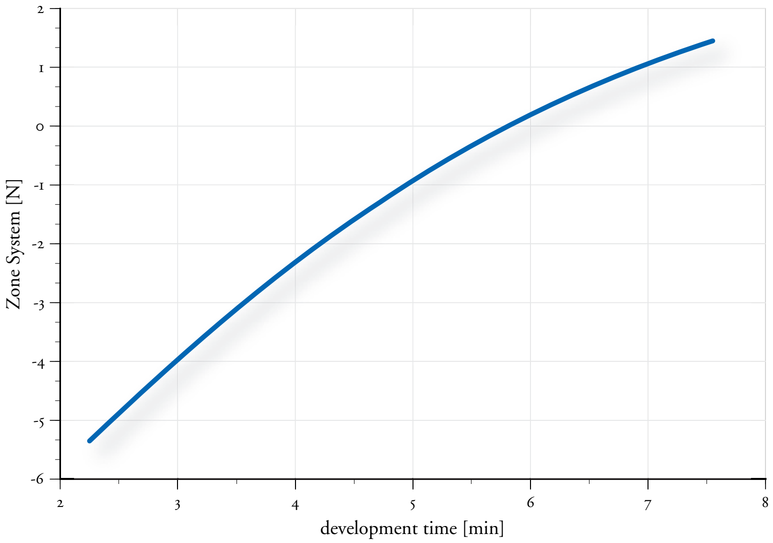


fig.6 Ilford XP2 is able to compensate for different subject brightness ranges by altering the development time, just as in the traditional Zone System.

## Material Testing

As in earlier chapters on film development, a test target, in this case a 4x5 inch Stouffer step tablet, was photographed repeatedly onto several films.

A standard 'press kit' was used, 100 ml of which was diluted to make 300 ml of working solution. Since the working solution was used for several tests, each development time was referenced back to the C41 standard for that number of processed films. In this case, two half rolls were developed at a time, so the normal 5% development extension per film was applied. On my old Jobo CPE-2, the high-speed agitation setting was selected and the water bath adjusted to 39.5°C. At this temperature, the developer, at completion, was exactly 38°C. Fig.2 shows alternative processing times for different operating temperatures, and fig.3 shows the standard corrections for chemistry reuse.

For this test, the step tablet was backlit and photographed with a 100mm lens mounted on a Fuji GX680 loaded with XP2 Super. The magnification of the image was such that the bellows compensation was exactly 1 stop. At this magnification, each density step was wide enough to be directly measured with a transmission densitometer. Camera aperture and shutter-speed accuracy had previously been verified and proved to be excellent.

Before taking any density measurements, a 13x print was made from each test film, using filter 5 to accentuate film grain. Unlike conventional films, XP2 or T400CN film grain does not appear in the highlights, but in the shadows. This is explained in the Ilford darkroom manual as a result of overlapping dye clouds, which prevent small holes printing as dark grains. There is, however, grain in the shadows, but the effect is small. The test prints were shuffled, and with some difficulty, ranked in grain size. The conclusion is that with small to medium enlargements, (10x), the grain easily outperforms a silver-halide emulsion of the same speed.

Density readings were taken from each test negative, using a Heiland densitometer. The results are plotted in fig.4. Each individual development time and temperature was recorded, so that the development times could be normalized in each case for fresh chemicals at 38°C. A note of caution: as with other processing tests, it is not always possible to reproduce exactly the same conditions in your own darkroom. This is especially true with the more critical C41 processing variables. Hence, the results in fig.4, 5 and 6 are based on my own darkroom conditions and should be viewed as an indicator.

The curves in fig.4 look conventional enough, with varying slope and foot speed. We can see that the film responds well to different levels of development and resembles standard silver-halide film curves. The 4-minute line really does tail off at high densities, giving extreme development compensation. This compensation, rather like the effect of using Pyro developer and two-bath formulae with conventional film, prevents highlights from blocking up. Many users can testify that this ability to roll off the highlights has salvaged many a high-contrast scene. Such a scene can be still be printed with good mid-tone separation and subtle detail in the highlights, something that is difficult to do with a silver-halide emulsion and reduced development.

## Film Speed

The standard development time of 3:25 minutes produces a low-contrast negative with a speed loss of about 1 2/3 stops from the published ISO 400/27° figure, based on our standard speed point at Zone I·5 with a negative transmission density of 0.17 above base+fog. One point to note is that the effective film speed, based upon a Zone I·5 shadow reading, can vary significantly with the development time. This is shown more clearly in fig.5, where the exposure index is plotted for different development times.

Fig.4 can also be interpreted to give the expansion and contraction (N) for different development times as is shown in fig.6. However, due to the low-contrast characteristics of XP2, we cannot base our Zone System calculations on the typical 1.20 density increase (0.17 to 1.37) over 7 zones (I·5 to VIII·5), because such a density increase is not obtainable through normal development times. Instead, we have to base the XP2 Zone System on a 0.83 density increase (0.17 to 1.00) over 5 zones (I·5 to VI·5) for N-2. The average gradient is about the same for both (0.57 versus 0.55), but the lower textural density range explains why XP2 negatives are typically printed on grade-4 paper. This method has proven to work well with my papers and filters.

The unique smooth tones of Ilford's XP2 Super and its Fuji and Kodak cousins, with their ability to cope with extremely wide subject brightness ranges, make these films worthy of merit, especially for landscapes and other high-contrast scenes. With fine grain, sensible longevity and the ability of push and pull processing, as well as the convenience of lab processing, this film has ousted most other high ISO 400/27° films from my refrigerator.

# Quality Control

## Continuous exposure and development control

Over the years, we have consumed most of the photographic texts in our libraries, and a few others besides. These texts include those by Adams, Davis, Henry, James, Mees, White, Thornton and Zakia. Although considerable emphasis is placed on film exposure, subject brightness range and development compensation, there is little attention paid to the concept of simple quality methods in the craft of photography.

For instance, after a considerable section on film measurement, characterizing exposure and development to the lighting conditions of the scene, it is assumed by some authors that the practitioner upholds repeatable lab practices, the materials never vary, and the equipment never wears. Of course, this is unlikely to be the case.

### Simple Photographic Controls

This is not a point to lose sleep over. We only want you to recognize that photography, just like a manufacturing process, suffers from variability in process, materials and human nature, all of which affect the final outcome. In industry, there are elaborate methods for working out all the variables, their significance and control by measurement and mistake proofing.

Our objective in photography is to eliminate the 'nasty surprises' and reduce the variability in our negatives and prints to within sensible limits. Although there are many variables associated with the picture making process (over 50), it is welcome news that only a handful are significant on a daily basis. Throughout this book, we have and will discuss several ideas to improve exposure accuracy, meter, camera and equipment testing, as well as good darkroom practices. The quality of the print is limited by the quality of the negative, starting with the exposure and continuing through to development and printing. Development control is especially important for users of fixed-grade paper, where effective matching of negative density range and paper contrast is critical.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50032-6

## Keep It Simple

We use a concept borrowed from the manufacturing industry for our film processing. We start most of our films with a test exposure. After development, the density information from this test gives valuable information about the exposure and development accuracy, and by comparing it to previous 'identical' films, also about exposure and development repeatability.

In one case, this test method identified the exhaustion of a developer concentrate. The film was a little underdeveloped and even though a slight correction in development time was made to bring it back on track, the next film was about the same. After a few months, the developing time was 30% longer than what it started at with the new bottle. Subsequently, although these negatives were printable, to bring things under better control, a protective spray was used to reduce developer oxidation and, as a precaution, the concentrate was stored in smaller bottles.

## All Change

For film processing, the principal process variables are time, temperature and agitation rate. The choice of developer, active volume and agitation technique are also significant but they are, for the immediate discussion, assumed constant. For a moment, let us consider an arbitrary emulsion and developer combination, Ilford Delta-100 and Tetenal Ultrafin. Let us say that the standard development time is 4.5 minutes with 300 ml Tetenal Ultrafin 1+20, at 24°C, with four tank inversions once every minute. The timer is started as the developer is poured in and emptied when 10 seconds of development time are left.

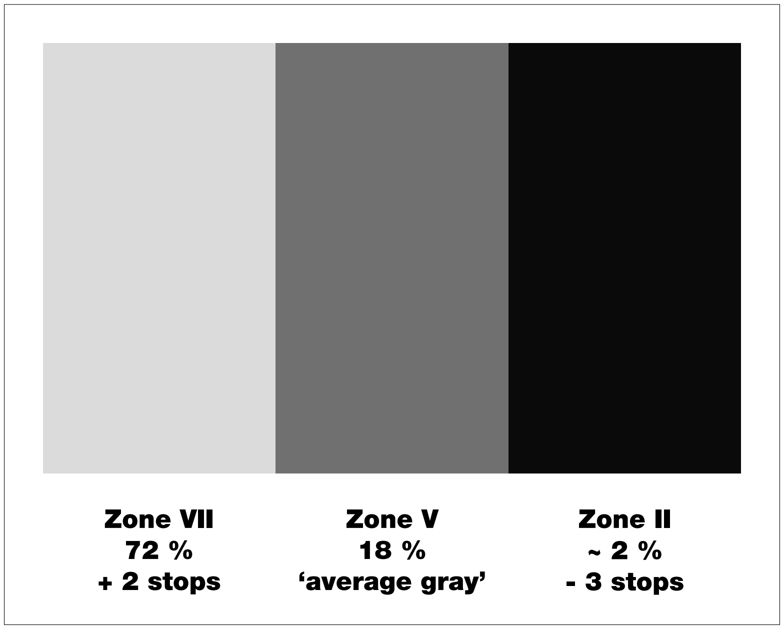


fig.1 This self-made test target simulates a subject brightness range of 5 stops and provides a useful alternative to the Kodak Gray Card.

Consider another session, when the development timer is started after pouring in the developer and emptied when the timer stops. In this case, the development time would be increased by 20 seconds, approximately 7.5%. Murphy's law states that accidents never happen one at a time; therefore, if at the same time the developer was above temperature by 1°C, it would increase effective development by a further 10%. Since bad luck always happens in threes, if we also agitated once every 30 seconds rather than every minute, we would increase effective development by another 10%.

Each process error has added a small overdevelopment, but the net result is a 30% increase on the original film development. This is enough to make you print with a full grade softer paper. If we rule out individual frame development for 35mm and roll film users, it is easy to predict that some negatives may well need the softest grade of paper for an acceptable print, without any room for any artistic maneuvers. Hence, in your darkroom, you should decide on the methods for temperature control, agitation and timing, and then stick to them and, consequently, measure their effectiveness with an ongoing quality test.

## Quality Testing with a Target

There is a descriptive and a measurement based approach to quality testing. Both require a test target (fig.1), which creates three negative densities when photographed. The resulting test negatives provide a regular check of your materials and technique, representing a typical highlight, average gray and shadow tone. Here we will only make use of the highlight and shadow tones, since they are the best indicators for exposure and development deviations. However, the average gray bar is included as a reference and it turns the test target into a useful alternative to the Kodak Gray Card.

The test target is readily made using an 8x10-inch sheet of printing paper, preferably in a semi-gloss surface finish. The semi-gloss provides a more consistent exposure range than a high gloss surface for an assortment of lighting conditions. Make a number of increasing plain dark test prints, record the print exposures and measure the brightness in comparison to a Kodak Gray Card with your spotmeter. Using the same lighting conditions that you have chosen for the test, find a print tone equal to that of the Kodak Gray Card, followed by another 3 stops darker and a third 2 stops brighter. They will serve as representatives of subject Zone V, II and VII respectively. Combine the test exposures to one print as in fig.1 and mount it to a piece of card. Occasionally, photograph the test target, which will tell you a lot about that film, as well as the repeatability, reproducibility and stability of your processing.

If you find numbers and graphs daunting, however, consider the evaluation chart shown in fig.2. With it, you can evaluate the highlight and shadow densities of the test negative. Use your subjective assessment to identify the extent of the required amount of exposure and development correction. This table is great for reminding oneself of the warning signs of poor negative control. However, it cannot tell you accurately the amount of correction necessary.

For this, a numerical technique is required where the test negative densities are compared to target transmission densities. These negative densities give important information. The density readings may show film-to-film randomness, hinting that your technique is not under strict control, or it may show a trend, which might be the influence of season, ambient conditions or developer exhaustion.

We recommend, at the beginning, to develop several films with identical exposure and development settings, to ensure that your technique is consistent. Keep good records of the time, agitation, developer and ambient temperature to remind yourself of the process. These records will also indicate where variability may be occurring. Once your technique is producing stable results, use the negative density data to correct for trends caused by aging film, developer and seasonal fluctuations.

By comparing the negative densities of these two standard exposures to a line on a graph, either the simplified one provided in fig.3, or one created from your own exposure and development experiments, you can determine an exposure and development correction for the next film. From all that has gone before, we already know, to some extent, that both highlight and shadow portions of a negative are affected by exposure and development. This makes life rather complicated, so we make what engineers call a 'first order approximation' and state that for small changes in development, the negative shadow density does not vary. Having made this approximation, we can say that exposure affects the shadow density while exposure and development affect the highlight density. In practice, we first evaluate the exposure correction with the shadow exposure density and then consider the difference between the shadow and highlight exposure densities

| negative densities | | **Development Zone VII** too weak | just right | too dense |
|---|---|---|---|---|
| **Exposure Zone II** | too dense | overexposed and underdeveloped | overexposed but correctly developed | overexposed and overdeveloped |
| | just right | correctly exposed but underdeveloped | correctly exposed and correctly developed | correctly exposed but overdeveloped |
| | too weak | underexposed and underdeveloped | underexposed but correctly developed | underexposed and overdeveloped |

fig.2 (top) The exposure and development evaluation chart allows for a subjective assessment of any required corrections.

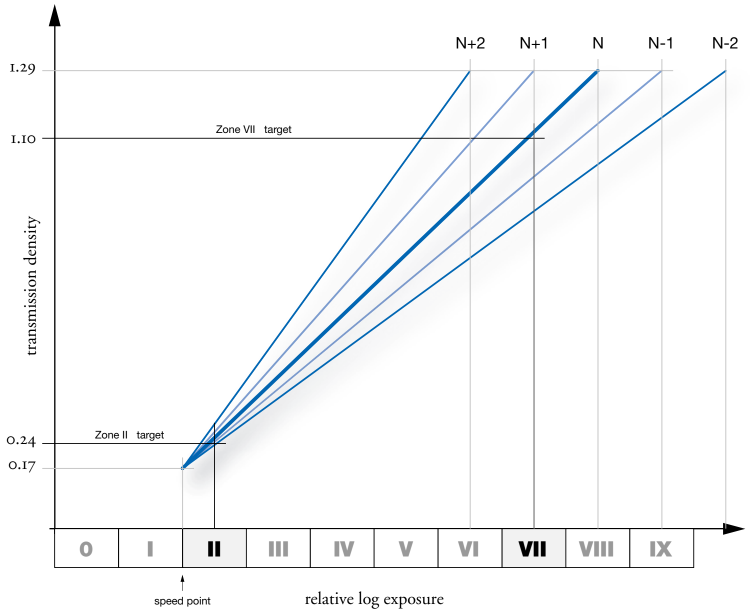


fig.3 (bottom) Actual test densities are compared with target values to predict exposure and development corrections in fig.4 and 5.

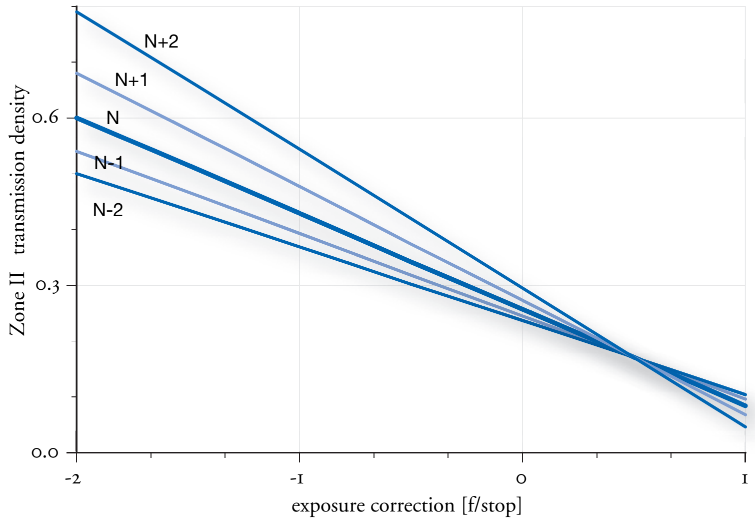


fig.4 (top) The actual shadow density of the test negative for a given development reveals the exposure correction needed.

to calculate the development correction. This will be explained fully later on, but for now, the important point is that, rather than making a complicated test, we can 'home-in' on the correct settings after a few films. In fact, for some, it is an alternative way to determine film speed and development settings by what mathematicians call 'successive approximation'.

## Exposure and Development Corrections

Depending upon your individual circumstances and film format, this test requires a single exposure of the test target in fig.1, or two separate frames, using different exposures, of a neutral evenly lit plain surface. In the case of a test target, the practical reflective properties of a flat object limit the subject brightness range to 5 stops. To ensure correct shadow exposure we assume that the low exposure represents Zone II and the high exposure represents Zone VII.

If separate exposures are made, then clearly the exposures should be 5 stops apart. In either case, we have assumed that one of these exposures is set to Zone II and the other is set Zone VII. Using these shadow and highlight values will enable you to clearly determine exposure and development corrections for a wide range of conditions. Whichever technique is used, to increase accuracy, extreme shutter speeds and apertures should be avoided, as well as close focusing and changing lighting conditions.

In fig.3, we have simplified the film characteristic curves to straight lines, crossing at the effective speed point and reaching the desired negative density at a Zone VI, VII or VIII. In fig.4 and 5, it is assumed that our test target, with its 5-stop brightness difference, has been photographed. When you photograph the target, set your spotmeter to your film exposure index for the chosen development, take a spot reading of the shadow bar, and place it on Zone II by reducing this exposure by 3 stops. To avoid flare and glare, use a lens hood and ensure that the lighting is principally off-axis and that there is no shadow over the test target, either when metering or exposing.

## Exposure Correction

Assuming the standard densities of Zone I·5 and VIII·5 exposures with N, N+1 and N-1 development set in the chapter 'Creating a Standard', and the film curves simplified into straight lines, it is possible to make a linear graph, as in fig.4, with which to calculate the exposure error. This exposure correction is applied to the exposure index used for this film, rather than some theoretical index determined at another time. In this way, if a film is slowly becoming less sensitive through age, the correction will track the change. Although this correction is based on a simplification of the complex film characteristic, the error it introduces is several times smaller than the error it removes. Some may find it useful to program a calculator or use a computer spreadsheet to record this information, calculate the corrections and plot the results to check how good your technique is.

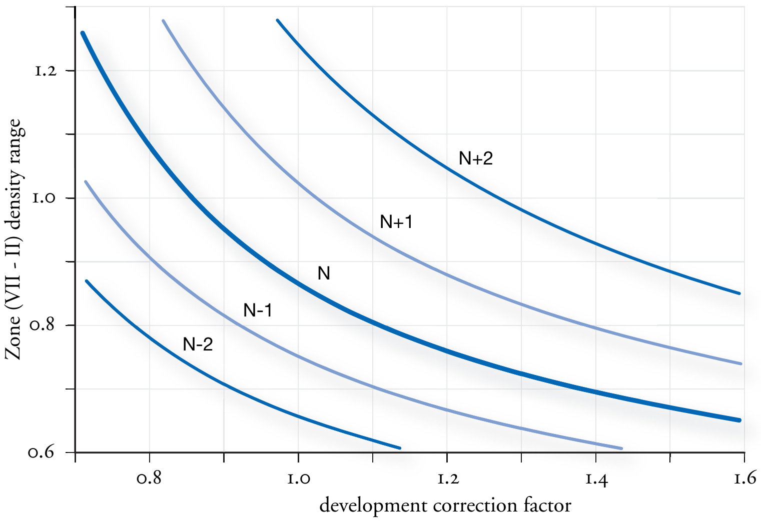


fig.5 (bottom) The actual negative density range of the test negative for a given development reveals the development correction needed.

## Development Correction

In a similar manner, the difference between the shadow and highlight densities can be used to give a predicted development time correction. In the graph shown in fig.5, it is assumed that the typical film/developer combinations require 25% more development, per zone of expansion and 15% less time for each zone of compression. These percentages hold good for many films and developers, with a few exceptions. TMax-100, for example, is usually about twice as sensitive to development than conventional emulsions. In contrast, extremely dilute or two-bath developers, both of which have a compensating effect, automatically reduce negative contrast variation. In these cases, you will need to measure your own film/developer characteristics and make your own graph for development corrections.

Fig.5 shows the development adjustments for three development schemes. To use this graph, take the difference between the Zone II and Zone VII densities, select the line that corresponds to your intended development scheme, and read off the development time factor from the other axis. Again, apply this factor to the last development time.

## Process Control

If you were to record and plot the various results for the exposure index and the development time for any film development scheme, the randomness of the points would indicate the degree of control exercised by the film manufacturer, your equipment, materials and technique. In particular, if film development times have more than +/-10% spread, the timing, agitation and temperature control methods that you use should be carefully checked. If, however, the points show little random variation, but form an increasing or decreasing trend, especially for development time, then the chemistry may be expiring, or the effect of season on the ambient conditions is playing its part.

Once you have proven to yourself that your technique is consistent, then it may only be necessary to check your material and equipment when new supplies are purchased or serviced. If you change printing papers, or use alternative enlargers for print contrast control, it may be necessary to tune your negative contrast to a new setting. This will then require new graphs for fig.3, fig.4 and fig.5, the generation of which is not shown here.

# Unsharp Masking

## Contrast control and increased sharpness in B&W

An unsharp mask is a faint positive, made by contact printing a negative. The unsharp mask and the negative are printed together after they have been precisely registered to a sandwich. There are two reasons to do this, the first being contrast control and the second being an increase in apparent sharpness.

Unsharp masks have been used for some time to control the contrast in prints made from slide film. They can also be used for B&W prints when the negative has an excessively high contrast due to overdevelopment. The mask has typically no density in the highlights, but has some density and detail in the shadows. Fig.9 shows how the sums of the densities result in a lower overall contrast when the mask is sandwiched with the negative.

However, this chapter is not about using an unsharp mask to rescue an overdeveloped negative, but rather to utilize this technique to increase the apparent sharpness of the print. A word of warning may be appropriate at this point. This is not for every negative, but more importantly, it is not for every photographer. It is a labor-intensive task to prepare a mask, and some printers may not be willing to spend the time involved to create one.

The technique is very similar to a feature called 'Unsharp Mask' in the popular image software Adobe Photoshop, but usually takes several hours to execute in the darkroom. The masks need to be carefully planned and exposed with the enlarger light, then developed and dried. Afterwards, it needs to be registered with the negative to a sandwich and printed. Batch processing several masks together cuts down on the time involved. Despite the workload, I would not be surprised if, once you have seen the dramatic difference it can make, you never print an important image without a mask again. Many fine-art photographers make masks for all their important images, and some

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50033-8

do not ever print them straight anymore, because few images look better printed without an unsharp mask. You may be less committed, but I hope this chapter will encourage you to try it out.

## How It Is Done

We start with the selection of an appropriate film to generate a mask. Specially dedicated masking film is either not available anymore, hard to come by or very expensive. For this reason, I now propose using either Ilford's Ortho Plus in Europe, or Kodak's TMax in the USA. Other film will probably do fine, but I have not tested them. Ortho Plus from Ilford has the advantage of being able to be handled under a strong red safelight, but it is, unfortunately, sometimes hard to find in the USA. I use 4x5-inch sheets exclusively to make masks for all film formats and see little reason to store masking film in different sizes. For me, it is easier to handle and store larger rather than the smaller film sizes.

The enlarger should be set up to allow for an even illumination to the entire baseboard with an empty negative carrier in place. A copy frame is helpful to hold the negative and the mask. Mine is made of plastic and has a gray foam backing with a hinged glass cover. A piece of 1/8 inch glass will do, however, if no copy frame is available. Place the mask film, supported by a piece of black cardboard, into the middle of the open copy frame, making sure that the emulsion side of the masking film is facing up, as in fig. 1. Place the negative on top of the masking film, again with the emulsion side facing up. Close the cover or hold the sandwich down with the glass.

The precise exposure may require some testing, but I have given you a starting point for the two films mentioned at the end of this chapter. Fig. 1 also shows how, during the exposure, the light passes through the emulsion of the negative first and then through the base of the negative to reach the emulsion of the mask. This base has a typical thickness of about 0.18 mm (0.007 inch) and it also diffuses the light slightly. This effect is responsible for the creation of a slightly unsharp mask. The thicker the base, the more the light is diffused and the mask becomes increasingly unsharp. Ironically, the unsharp mask is responsible for the sharper image when printed later as a sandwich. It is common practice to use clear plastic spacers, available from art supply stores, between the negative and the mask to increase the effect, but I find that it looks unnatural. Therefore, I do not use spacers anymore. However, you may want to experiment with clear plastic sheets of 0.1-0.2 mm (0.004-0.008 inch) thickness, to find the effect you prefer.

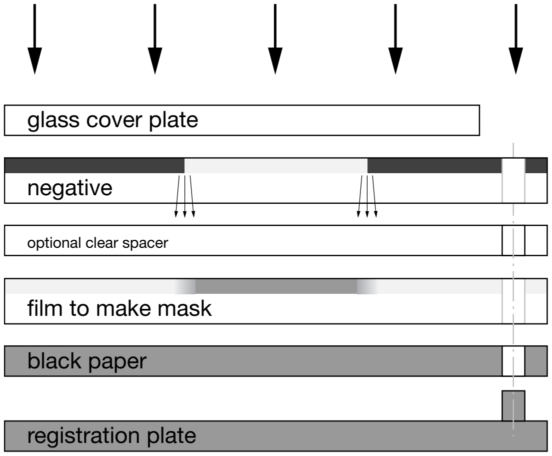


fig.1 Negative and unexposed masking film are placed, emulsion side up, on top of the baseboard. The carefully planned exposure creates a faint and slightly unsharp positive, called the unsharp mask. An optional plastic spacer may control the degree of sharpness.

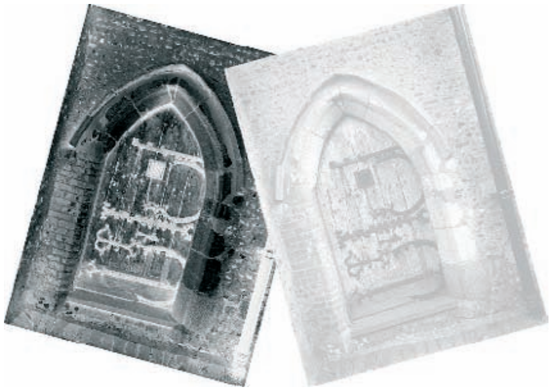


fig.2 Negative and unsharp mask will be printed together as a precisely registered sandwich. This reduces the overall contrast of the negative, but increases edge sharpness and local contrast of the print.

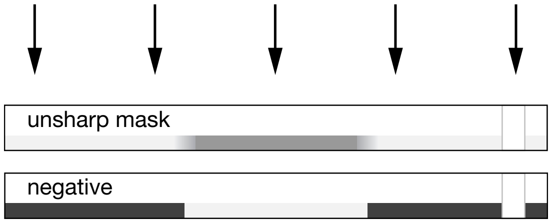
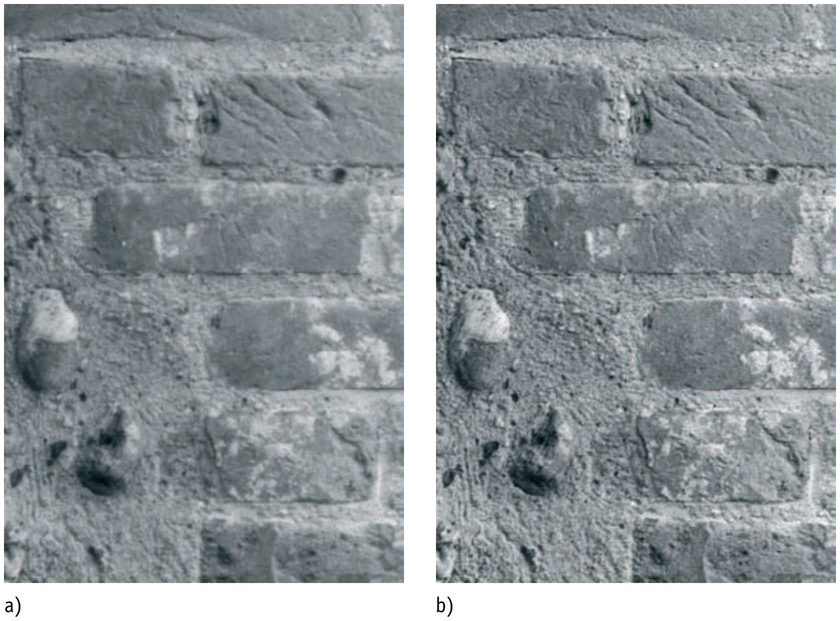


fig.3 The registered sandwich is placed into the negative carrier and printed together with the emulsion side down. The increase in required paper contrast and the 'edge effect' create a sharper image.

After the exposure, process the mask as you would any other film. The developing times mentioned at the end of this chapter are starting points and they


a)

b)

fig.4a-b These two examples show a detail of the brickwork to the left of the door. Fig.4a was printed with the negative alone, and fig.4b was printed with the negative and the mask registered to a sandwich. The increase in local contrast and edge sharpness is significant and clearly visible. Paper grade 2.5 was used for fig.4a and increased to grade 4.5 for fig.4b to compensate for the reduced contrast of the sandwich.

work well for me. I use a Jobo processor with constant agitation, but your times may differ if you use a different method. Fig.2 shows the negative and the mask for the cover photo.

The negative and the mask are sandwiched, as shown in fig. 3, in order to print them together. Relatively expensive pin-registration equipment is available from several sources, and I have tried a few of them. Nevertheless, patiently aligning the negative and the mask manually, with a piece of tape and a loupe on a light table, works well with a bit of practice, and I suggest you try that first. You may decide that masking is the way to go, and then, the purchase of such equipment may be a wise investment.

## What a Difference

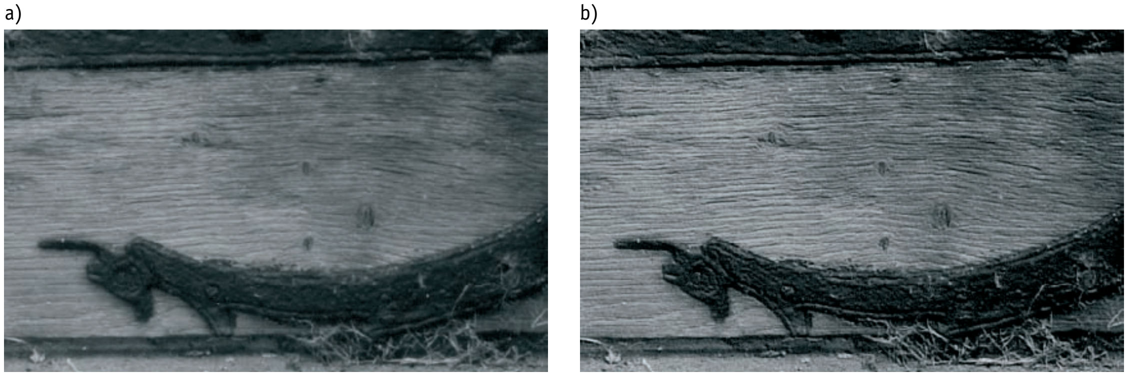
The lead image shows the north door of St. Mary of Buttsbury in Essex, one of my favorite English churches. The original negative density required a paper grade of 2.5 and, being taken with a 4x5 camera, produced a rather sharp image. The image reproduced in this chapter was printed including the mask and it reduced the contrast of the sandwich to the point that a paper grade of 4.5 was necessary. The result is significantly sharper than the print from the negative alone. The enlarged details in fig. 4 and 5 demonstrate the difference well. You can probably guess that figures 4b and 5b were printed with the mask.

In order to be fair to the original image and not to generate unrealistic expectations, it must be noted that the difference is much more obvious when the two techniques are compared side to side. The original print is very sharp in its regular size of 11x14 inches, but the masked negative produced a print of increased local contrast, clarity and apparent sharpness.

## Why It Works

It might interest you why unsharp masks work, now that we know how it is done and what a difference it can make. I am aware of two governing phenomena for unsharp masks to increase sharpness.

You have probably noticed the first phenomenon during regular darkroom work already. A print just looks sharper when printed on a higher contrast paper. Figures 6 and 7 demonstrate this effect in form of an example and a diagram. In both cases, the same negative was printed onto paper of different contrast range. The same effect can be observed when the highlights are printed darker. This is similar to using a higher contrast paper, because the increased exposure causes


a)

b)

fig.5a-b These two examples show a detail of the lower right hand side of the door. Here the difference in sharpness is clearly visible between negative fig.5a and sandwich fig.5b.

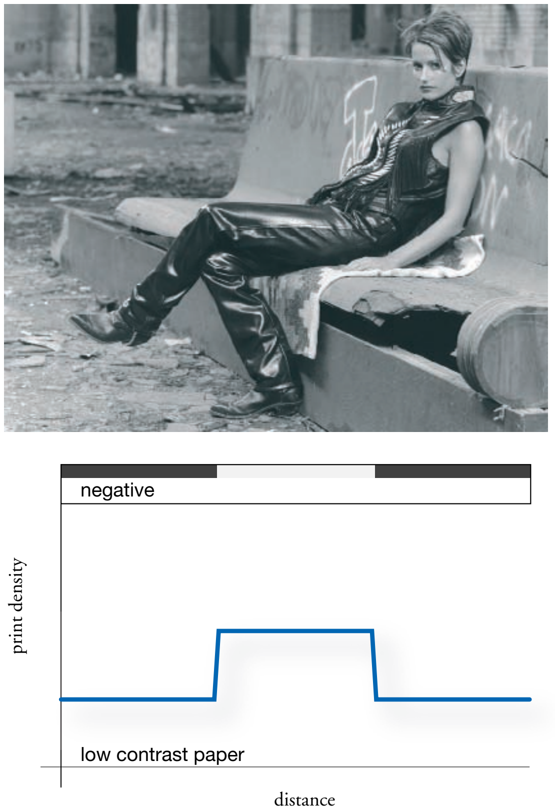


fig.6 A normal negative printed onto low-contrast paper creates a modest density difference between shadows and highlights. Print shadows are weak and midtone contrast is low. The image appears to lack sharpness.

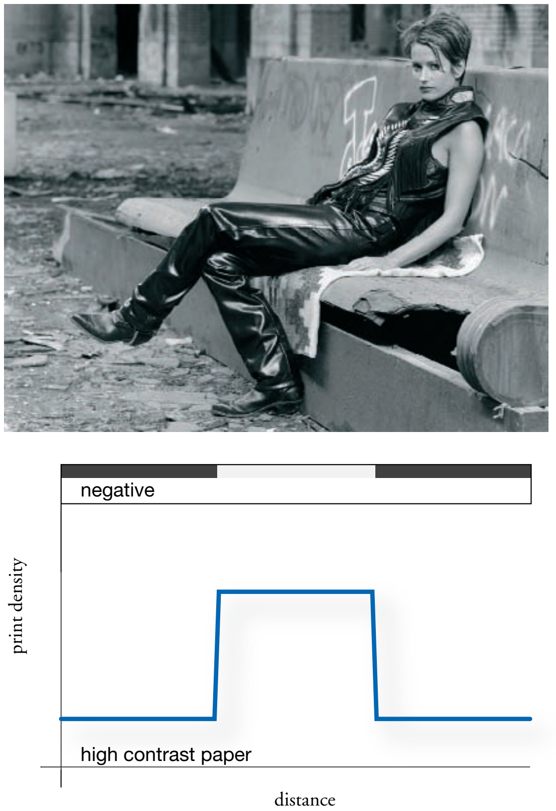


fig.7 A normal negative printed onto high-contrast paper creates an increased density difference between shadows and highlights. Deep shadows and high midtone contrast make for a sharper image.

the density in the darker highlights (Zone VII) to increase more quickly than in the brighter highlights (Zone VIII), due to their relative location on the toe of the characteristic curve. In either case, the result is either a local or an overall contrast increase.

The second phenomenon is explained in fig.8 and is referred to as acutance, edge contrast or simply as the 'edge effect'. You see the negative and the mask sandwiched together. Looking at the sandwich density and reading from left to right, there is a relatively high density up to point 1, responsible for a relative low density in the print. At point 1 this changes, because the fuzzy edge in the mask causes the sandwich density to increase up to point 2, while the print density is lower than the adjacent highlights. Of course, at point 2 things change again, because the sharp negative edge

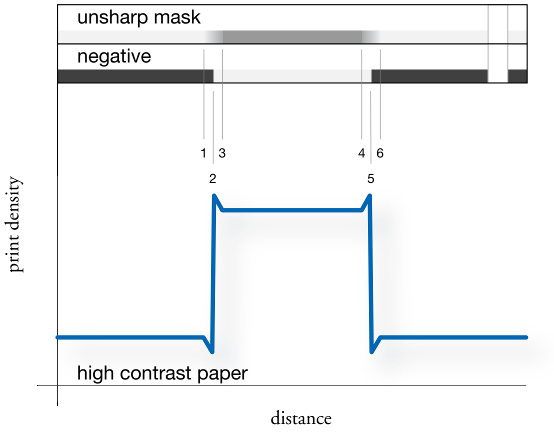
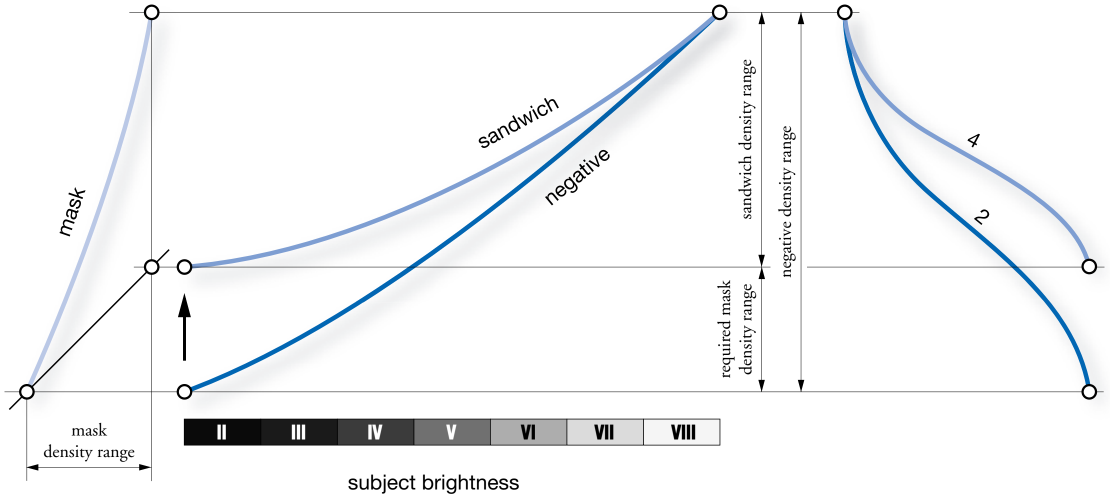


fig.8 A higher contrast paper is required when a negative is printed together with an unsharp mask. This alone increases apparent image sharpness. Additionally, the 'fuzzy' edges of the unsharp mask increase the density differences at all image contours, which raises acutance and creates an 'edge effect', increasing image sharpness even further.

fig.9 A typical negative has a high density range and requires a paper grade-2 to print well. A mask can reduce the shadow density while not affecting the highlight density. The resulting sandwich prints well on a higher paper grade while raising local contrast and sharpness.



is now switching to the shadow area and the print density increases sharply. However, the fuzzy mask does not reach its highest density until point 3 where the print density finally settles. The reverse effect can be observed from point 4 to point 6, at which the print reaches the final highlight density again.

In summary, when using an unsharp mask, a higher paper grade is required, due to the contrast reducing effect of the mask, which creates an 'edge effect' at the boundaries of highlights and shadows. Both phenomena work together to increase the apparent sharpness of the print.

## Planning a Mask

This section of the chapter is aimed to guide you in the successful planning of the exposure and development of the masking film. I made a special effort to consider photographers who are fortunate enough to own a densitometer, as well as the more traditional darkroom enthusiast, who is more familiar with paper grades. In both cases, we will determine the original negative characteristics, and then design a mask to change it to a desired sandwich characteristic. Fig.9 and fig.10 will work in combination with each other to help with the understanding of the process, the evaluation of the negative and the design of the mask.

| negative density range | paper grade | sandwich paper grade | | | | |
|---|---|---|---|---|---|---|
| | | **1** | **2** | **3** | **4** | **5** |
| 1.55 | **0** | 0.25 | 0.50 | 0.70 | 0.85 | 1.00 |
| 1.30 | **1** | | 0.25 | 0.45 | 0.60 | 0.75 |
| 1.05 | **2** | | | 0.20 | 0.35 | 0.50 |
| 0.85 | **3** | | | | 0.15 | 0.30 |
| 0.70 | **4** | | | | | 0.15 |
| 0.55 | **5** | **mask density range** | | | | |

fig.10 Negative density range and paper grades have a defined relationship. A target paper grade for the sandwich will determine the required mask density range.

We will begin with the evaluation of the overall density range of the negative to be printed. If you have a densitometer, take a density reading of the important highlights and shadows and calculate the difference. Fig.10 suggests a negative density range, if you know the paper grade at which the negative printed well. For example, let's assume that you determined a negative density range of 1.05, which is equivalent to a paper grade-2, as shown in the table. Now, estimate how much the local contrast needs to be raised. This depends on the image itself, your intent for the image and your personal taste, but raising the paper contrast by two grades is common. To continue our example, you want to raise paper contrast from grade 2 to 4, which requires a mask density range of 0.35 as shown in the table.

The graphs in fig.11 will help you with the exposure and the development of the masking film. The development times are starting points, which were tested with my Jobo processor and constant agitation in my darkroom. We will use the previously determined negative and mask density ranges to find the appropriate development time. The negative density range is on the vertical axis and the mask density ranges are plotted as individual curves from 0.3-0.7 in 0.1 intervals. In our example, assuming Kodak's TMax-400 for a moment, picture a horizontal line at 1.05 negative density. Then, interpolate a curve between 0.3 and 0.4 to represent a desired mask density of 0.35, and estimate the intersection with that horizontal line. This gives a development time of about 7.5 minutes. The exposure index changes with the development time and the table to the right recommends an EI of 160 for a 7.5-minute development time.

The exposure times for both films are assumed to be 1/4 of a second given an illumination of EV of -3.0 on the baseboard. I have used a Durst color head with a halogen light source, no filtration, and again your conditions may vary, but it should be a good starting point. The other assumption is a negative highlight density of 1.37, my standard density for Zone VIII·5, and the exposure must be changed to reflect the highlight density of the target negative. This is easy, using a densitometer, since a density of 0.3 is equivalent to 1 stop of exposure. Bracketing the exposure is advisable without the use of such a tool.

As you may have noticed, I have chosen to use rather short exposure times, below 1 second, to stay within the reciprocity window of the film. Therefore, I mount one of my large format taking lenses to my enlarger. This assembly allows me to use the shutter to get any of the typical exposure times between 1/500 and 1 second. Typical enlarger timers do not allow precise timing in this range, and I suggest using longer times of several seconds if you cannot utilize a large-format taking-lens. Modify the illumination by changing the aperture of your enlarging lens, and perform your own tests to get the right exposure and contrast of the mask. Be aware that the reciprocity failure of conventional films may generate an increase in contrast if the film is exposed longer than 1 second. Modern films, like TMax, Delta and FP4 are less sensitive to this effect.

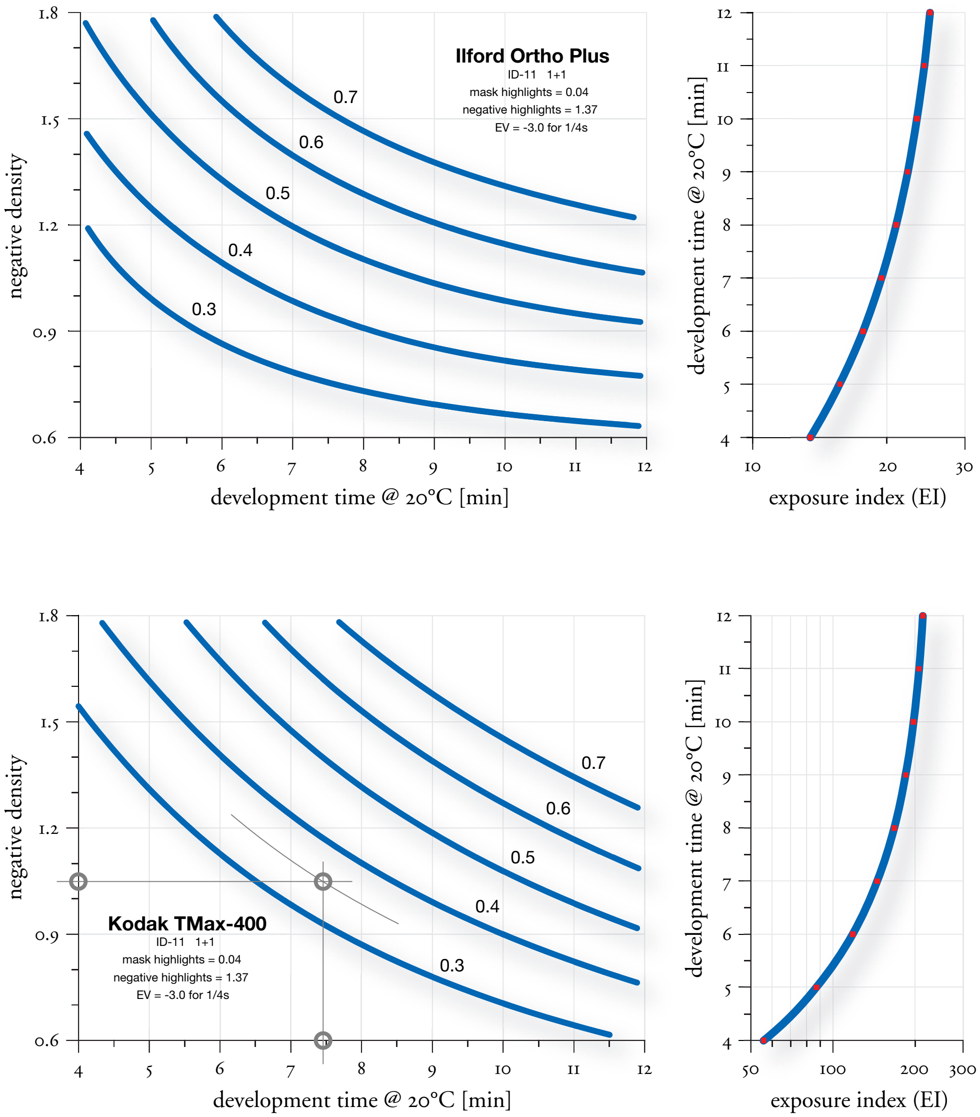


fig.11 Planning a mask is easier with starting point values for development time and exposure index for two films. The input variables are negative and mask density ranges.

# Masking for Complete Control

## More masks, more opportunities for control

by Lynn Radeka

Land of Standing Rocks, 1988 - Canyonlands National Park, Utah

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50034-X

Along the remote region of Utah's Canyonlands National Park known as the Maze District, I noticed an interesting sweeping cloud formation moving toward the east. Recognizing a potential photograph, I quickly stopped my vehicle and set up my 4x5 camera. The cloud moved into perfect position in relation to the coarsely textured standing rocks, and I made two exposures on Kodak's Tri-X film using a deep yellow filter to darken the sky a bit and cut through some of the distant haze. After shooting the second exposure, I noticed that a jet trail had encroached into the image area. My only good negative came from the first exposure (without the jet trail), and I call it 'Land of Standing Rocks'. It is a very difficult image to print, and the main challenge was achieving a sense of luminosity and desert light, while simultaneously avoiding excessive contrast. Aesthetically, this image symbolizes to me the vast and open wilderness of the American West, but it is also a good example of masking for complete control.

## Masking

The unsharp mask, in its various forms and names, has been around for quite some time, during which its primary use has been in the production of color prints from transparencies or negatives. This process often required the need for reduced contrast. A contrast reduction mask, a variation of the unsharp mask, helps to reduce the overall contrast of the transparency, allowing the full tonal range to print on the relatively high-contrast medium.

In B&W work, there are many other problems that we face when attempting to achieve a fine print. Many of these problems cannot be solved by meticulous exposure, processing and/or printing alone. Fortunately, there are many opportunities for creative control when it comes to masking. Masks can be made to increase highlight contrast or brilliance, or to increase local contrast within the shadow values. Masks can also be fashioned to act as accurate flashing tools, useful for smoothing out excessively bright, distracting areas of the image. Similar masks can be used for accurately burning down the sky areas without affecting adjacent values. Masks can also be made to selectively lighten certain elements of the image, better separating those elements from surrounding values. This highlights important image elements and creates enough impact to draw the observer into the picture.

## Pin Registration

Although the unsharp mask and the contrast reduction mask can be registered with the original negative by eye, some masks, particularly the Shadow Contrast Mask, require the use of an accurate pin-registration system for accurate creation and usage. Such a system can be made by the photographer, using metal registration pins and a two-hole punch of the same diameter as the registration pins. My Contrast Masking Kit contains full instructions on making such a system for your own darkroom. Essentially, the method is to produce a glass carrier for the negative, with a set of metal registration pins taped or fastened permanently to it. This carrier must also be placed in the enlarger at precisely the same position every time, which again requires the carrier to be registered in some way to the negative stage in the enlarger. This can be done with another set of registration pins fastened to the enlarger negative stage. The objective is that each time an original negative or a mask is placed in the enlarger, it is placed in exactly the same position, in order to avoid misalignment when multiple exposures are made on one sheet of photographic paper. Once a good pin-registration system is made, it becomes a simple and efficient task to prepare and print with a number of different masks.

## The Shadow Contrast Mask (SCIM)

One of the most useful masks in my work, and I believe one of the most powerful masks in general, is the Shadow Contrast Mask. Not a true mask in the technical sense, this mask is actually a separation negative. It was primarily designed and proposed by photographers Dennis McNutt and Marc Jilg, and its full name is Shadow Contrast Increase Mask or SCIM. It is primarily used to enhance the contrast within shadow or midtone values, while leaving highlight values completely unaffected. The degree of effect this mask has in printing is absolutely remarkable, as you can see in comparing fig.4 and fig.6, taken at Zabriskie Point.

It should be noted that the effect of this mask, either dramatic or subtle, could not be duplicated by altering one's exposure or printing routine. Furthermore, the use of this mask allows the photographer to take advantage of the maximum tonal range of the paper. The use of the Shadow Contrast Mask literally increases the depth of the black accents in the fig.1 Making the interpositive for the SCIM. Litho film is placed emulsion up in a pin-registered glass carrier, with the original negative, also pin-registered, placed emulsion down so that the emulsions are touching. The glass carrier is closed and the ensemble given an exposure with a controlled light source. The resulting interpositive should look like a fairly thin black and white transparency.

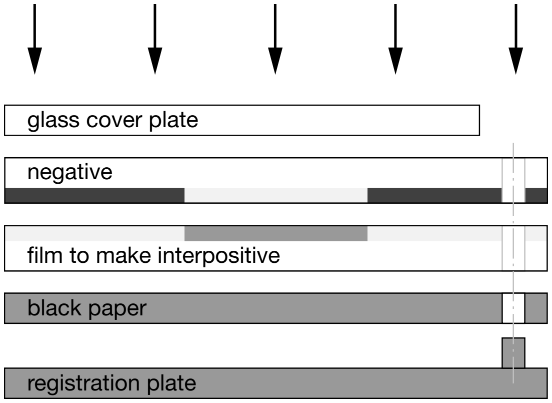


fig.2 Making the SCIM. Litho film is placed emulsion side up in a pin-registered glass carrier, and the interpositive is placed on top, emulsion to emulsion. The glass carrier is closed and the ensemble given an exposure with a controlled light source. A good SCIM should look like an extremely high contrast negative, with fairly clear shadow accents and completely opaque midtones and highlights.

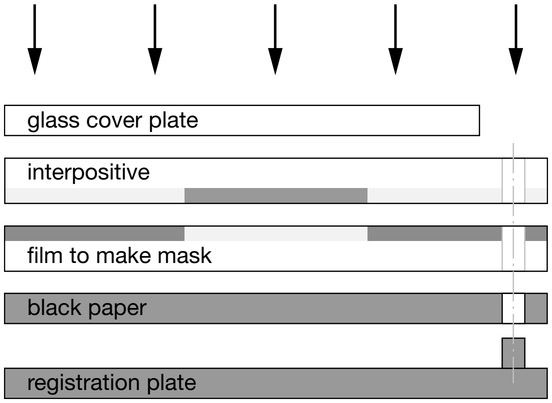
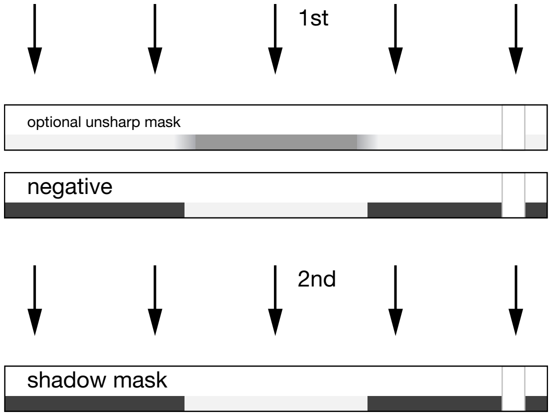


fig.3 Printing with the SCIM. Using a pin-registered glass carrier, the original negative (along with any unsharp mask or highlight mask sandwiched with it, if desired) is given an initial exposure with any appropriate dodging and burning done during this step. After the exposure, the contents of the glass carrier are replaced with the SCIM and a second exposure is given to the paper. The effect is a deepening of the darkest values resulting in more vitality in the shadows.



image, often to the point where the accents achieve maximum black and serve as a visual key. The result is an amazing increase of life and vitality in the broad shadow values, which contribute to the overall tactile quality of the print.

Without the use of the Shadow Contrast Mask, a standard print often exhibits relatively flat, somewhat empty shadows. This is particularly true in high-contrast scenes containing a rather high subject brightness range, where the negative was exposed and processed to compress the range in an attempt to control all the values and increase the ease of printing. Merely resorting to a higher contrast paper grade and exposing the print a bit lighter, in an attempt to keep the shadows from going excessively dark, may help the local contrast in the shadows, but the highlights may burn out and the midtones may become too light.

The Shadow Contrast Mask is extremely effective when used in combination with an unsharp mask or contrast reduction mask. These serve to reduce the overall contrast of the image as a whole, particularly by raising the shadow values somewhat. This assumes that the photographer does not want to select a higher paper grade when using the unsharp mask, as doing so may increase the highlight contrast too much. Without the Shadow Contrast Mask exposure, the print may exhibit fine, open shadows with plenty of obvious detail, but the shadows may look dismally flat and gray, lacking local contrast. However, if the paper is given a follow-up exposure using the mask, open shadows will be brought to life by deepening the fine dark accents to black or near-black depending on your intent. The results can be striking.

### Making the Shadow Contrast Mask

Typically, the Shadow Contrast Mask is made in a two-step process, using ordinary litho film and any standard print developer. A one-step method using Kodak LPD4 positive litho film is also possible, but it affords a little less creative control. Using the pin-registration glass carrier placed on the enlarger baseboard in a central area of the light circle, a punched sheet of unexposed litho film is placed on the pins of the carrier emulsion-side up. The original negative, with a punched strip of leader film taped to it, is placed on the litho film emulsion-side down so that the two sheets of film are emulsion to emulsion. The top glass is closed on the ensemble and an exposure is made

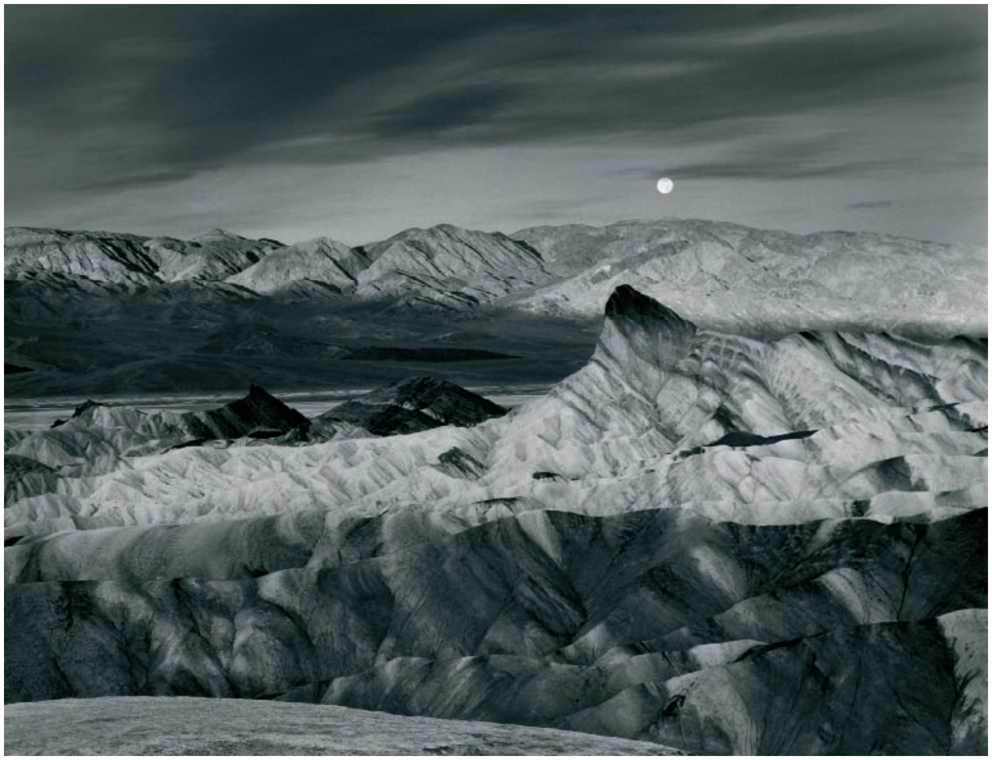
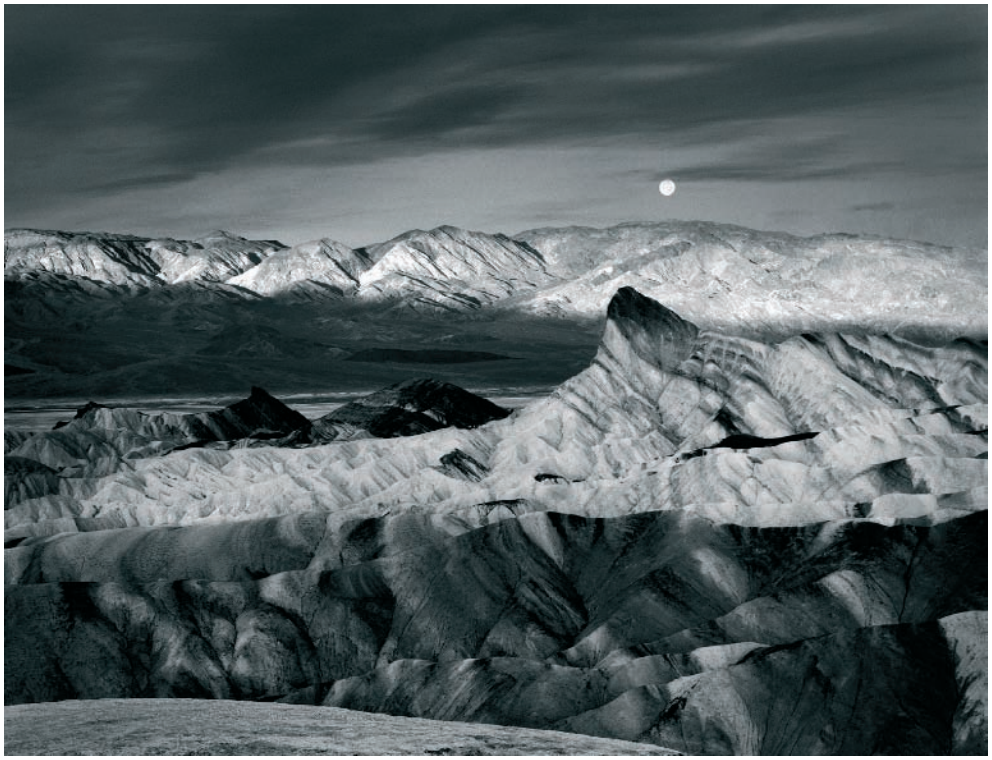


fig.4 Moon Over Zabriskie Point, 1980 - Death Valley National Park, California. Shortly after sunrise, I photographed Zabriskie Point as the moon began to lower in the western sky. Within a minute after this exposure, clouds began to cover the moon. I like the look of the lunar-like landscape set against the setting moon. The negative contains excellent detail throughout, and the original print shows surface details in the moon. My first attempts at printing this back in 1980 were futile. A decade later, I reexamined the potential expressions of this image and successfully achieved my desired print in fig.6.



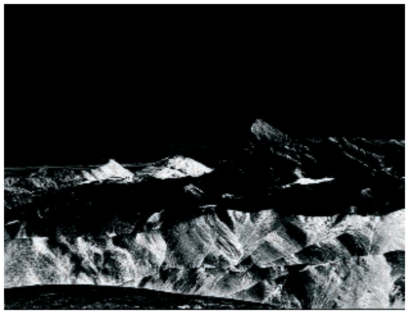


fig.5 (top) SCIM used in making the final print. Note how the deep shadow values and black accents will print through affecting the foreground mud hills.

fig.6 (left) Final print using a SCIM to enhance the local contrast within the dark values of the foreground mud hills. Unlike the results that would occur with a paper grade change, the midtones were unaffected. I applied a highlight brightening bleach to lighten and increase the contrast of the background mountain range.

with the enlarger or any other controllable light source. The litho film is developed in a fairly dilute solution of print or film developer at a standard temperature. The resulting interpositive is examined after fixing and judged for the proper exposure and contrast. A good interpositive should look like a thin B&W transparency, with plenty of detail showing in the shadow areas. The shadow areas must not be too dark and are ideally on, or around, the middle of the characteristic curve. The final, properly exposed and developed interpositive is washed and dried normally.

Next, place a punched sheet of litho film in the pin-registration glass carrier emulsion-side up as before. This time, the interpositive is placed emulsion-side down on the litho film in the carrier, again so that the films are emulsion to emulsion, and the carrier top glass is closed on the ensemble to hold the film in tight contact.

As before, the ensemble is given an exposure with the enlarger light, and the litho film is developed in a stronger solution of paper or film developer. This developed litho is the Shadow Contrast Mask, and looks pure black everywhere except in the deepest shadow accents, which are nearly clear. It takes a little experience to develop an eye for a proper Shadow Contrast Mask, but once you see how it affects the final image, a good mask will spring out at you.

### Printing with the Shadow Contrast Mask

When printing with the Shadow Contrast Mask, the paper is given the first exposure as usual with the original negative, perhaps sandwiched with another special mask. Without touching the paper in any way, the carrier is removed from the enlarger, the negative is replaced with the Shadow Contrast Mask, and the carrier is returned to the enlarger. The paper is given a second exposure with the mask, which serves to deepen the darkest accents within the shadows. You must test, as usual, to determine the desired exposure.

The Shadow Contrast Mask can overcome practically any flattening problem that results from low-contrast paper, the use of contrast reduction masks, soft developers, etc., and can be one of the most valuable creative tools in the darkroom worker's arsenal. Once the carrier is made and some initial tests are done, the ease and speed with which one can make and use the Shadow Contrast Mask makes this a very useful tool for improving print quality.

## The Highlight Mask

It can be somewhat frustrating when we examine the finished dried print after a long day's session in the darkroom. The wet print had far more luminosity, and the highlights were bright and crisp. When dry, however, the highlights tend to lose brilliance to the surrounding areas, giving the entire image a somewhat dismal gray look. Localized highlight bleaching, commonly done with Farmer's Reducer or with my print bleach formula, detailed in my Contrast Masking Kit, is certainly an option during the printing session. However, it can be a time-consuming process, as it must be hand-applied to each print individually. An effective alternative, particularly useful if multiple prints must be made and consistency is important, is the Highlight Mask.

Essentially, the Highlight Mask is custom tailored to the original negative, to produce just the right amount of highlight contrast enhancement, subtle or dramatic, in certain areas. Compare fig.7 and fig.9 taken in Marble Canyon. Once the Highlight Mask is made, it can be used repeatedly to produce consistent results, regardless of print size. Furthermore, the Highlight Mask can be adjusted in density and contrast for finer creative control over the resulting print highlights, and areas of the Highlight Mask can be bleached clear (on the mask itself) so it affects only the desired areas of the image.

### Making the Highlight Mask

As in the making of a Shadow Contrast Mask, either a two-step procedure, using standard litho film, or a one-step procedure, using LPD4 film, can be followed. This chapter will discuss only the two-step procedure, since as of this writing (2002), standard litho film is much easier to find than positive litho film. Additionally, the two-step procedure allows for greater creative control.

With a pin-registered glass carrier placed on the enlarger baseboard, a punched sheet of litho film is placed emulsion up in the carrier. On top of that, the original negative with a punched leader taped to it is placed emulsion-side down on top of the litho film so the emulsions are touching. The glass carrier is closed to assure the films will be in contact with one another. The film is given an exposure with the enlarger light, removed from the carrier and developed in a fairly dilute solution of print or film developer. After fixing,

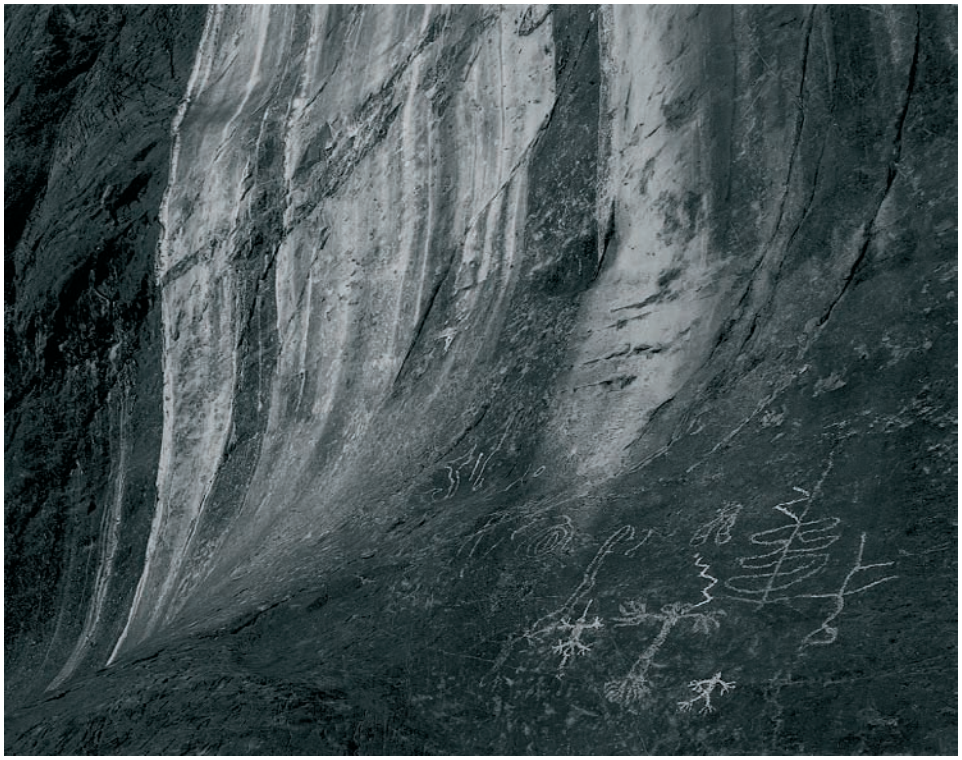


fig.7 Marble Canyon Petroglyphs, 1987 - Death Valley National Park, California. A short hike at the end of a rough road in a remote canyon in Death Valley leads to this interesting set of Indian petroglyphs. Located high up on a rock shelf, my assistant affixed a rope to my backpack containing my 4x5 camera, which I carefully pulled up to the appropriate camera position. The striated rock wall looming above the petroglyphs formed a sort of visual curtain opening above the rock drawings, forming a sort of stage setting. I shot one negative with an orange filter, which revealed the primary shapes more intensely. In an effort to separate the essential forms, I could have used a higher paper grade, but doing so would increase the differences in the dark rock values to a disturbing degree.

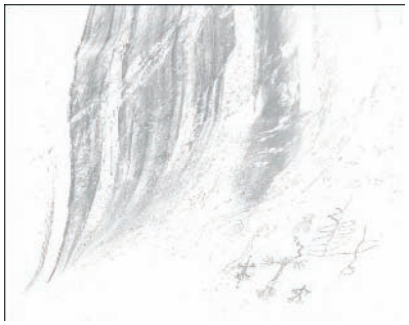


fig.8 (top) Highlight mask used in printing the final image, and viewed against a white paper background.

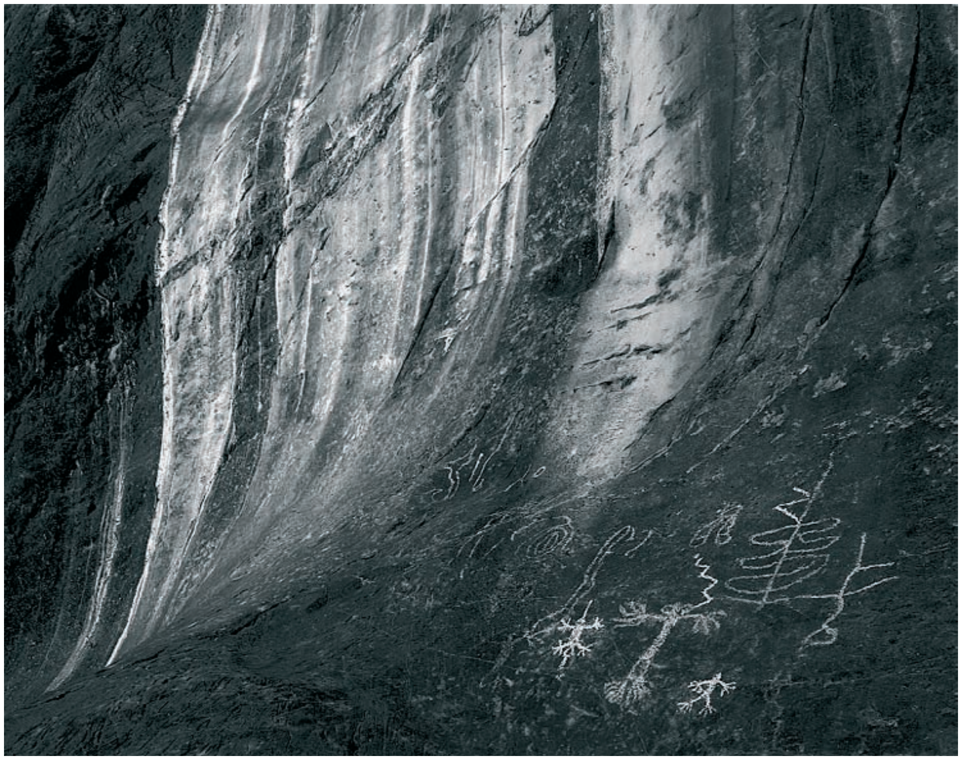
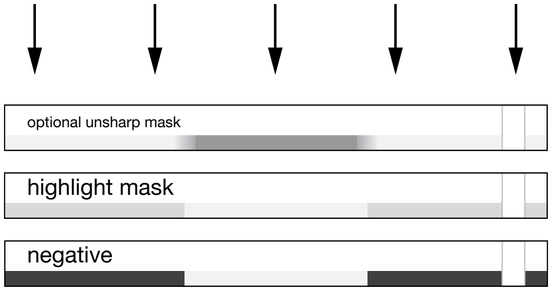


fig.9 (left) Final print made with a highlight mask sandwiched with the original negative. Note the contrast and brightness increase seen only in the areas affected by the mask.

fig.10 Orientation of highlight mask sandwiched with original negative in a pin-registered glass carrier when printing. Any other masks, such as unsharp mask, that the photographer uses should be placed on the top position in the ensemble.



this interpositive is evaluated to determine the proper exposure. A good interpositive for a Highlight Mask looks like a rather dark and somewhat low-contrast B&W transparency when viewed with transmitted light. In particular, the highlights of the image should show plenty of detail and should not appear burned-out or clear. Flexibility and creative control can be exercised here by adjusting the exposure and contrast of this interpositive.

This dried interpositive is used to make the final Highlight Mask. An unexposed sheet of litho film is placed in the pin-registered glass carrier emulsion-side up, and the interpositive is placed on top of it emulsion-side down, again, so that the emulsions are in contact with each other. The glass carrier is closed and the ensemble given an exposure with the enlarger light.

The newly exposed Highlight Mask is then developed in approximately the same dilution of print or film developer, fixed and washed. When evaluating the Highlight Mask, the highlight areas of the image should show only slight density, while all other values are absolutely clear. Remember, this is a severely underexposed negative image, but it resembles the original negative. It shows absolutely no detail, other than in the brightest highlights, where we wish to brighten the resulting print.

### Printing with the Highlight Mask

This printing mask is used in the same way as an unsharp mask. The original negative is placed in the pin-registration carrier emulsion-side down, and the Highlight Mask is placed on top of it emulsion-side down as well. The carrier is closed so that the two films make good contact and the ensemble is used to print. When using the Highlight Mask, it becomes obvious very quickly that even a very thin and low-contrast mask can have a very dramatic effect on the highlights of the image. If an unsharp mask is used in conjunction with a Highlight Mask, the Highlight Mask is placed closest to the original negative, with the unsharp mask on the very top of the ensemble.

I began using Highlight Masks in my B&W work, in one form or another, back in the late 1970s. One tactic I often employed was to design the Highlight Mask so that its primary effect increased contrast in the midtones of the image. This usually required blocking out certain areas of the interpositive with a black felt pen so that those areas, usually bright highlights, which I did not want affected by the Highlight Mask would not yield any density on the final mask. In this way, I was able to design Highlight Masks to selectively raise the brightness and contrast of certain midtones and occasionally even large, open shadow areas.

## The Fog Mask

The majority of my prints are improved by darkening unwanted bright areas of the image, such as specular reflections on leaves in a forest scene or distracting bright rocks or branches. Photographers often employ various techniques designed to darken or soften harsh, disturbing highlights that distract from the essential elements of the image. These methods are sometimes called flashing or fogging the print and are discussed in detail in the 'Print Flashing' chapter. The print is given a non-image forming local or overall pre-exposure to sensitize the emulsion so that the slightest additional exposure is recorded on the paper. This technique reveals subtle values in highlights, which might otherwise become textureless, burned-out whites. Flashing techniques can also be used to subdue other distracting areas, and when combined with burning, allow the photographer greater creative control over the final image.

One problem with flashing the print in localized areas is that it is difficult to know precisely where to flash, as the image cannot be seen when using non-image forming light. Placing a deep red filter under the lens to prevent exposure allows you to see the image while using a special penlight to flash the print, but it is a somewhat inaccurate technique, and it is impossible to flash specific areas precisely without affecting adjacent areas.

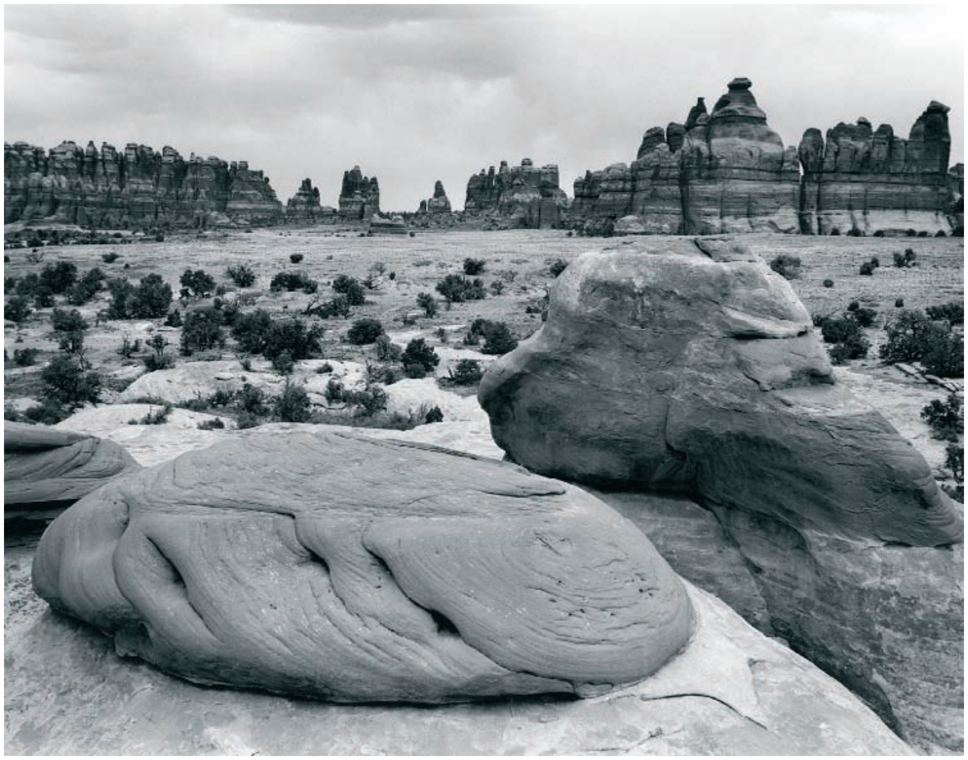
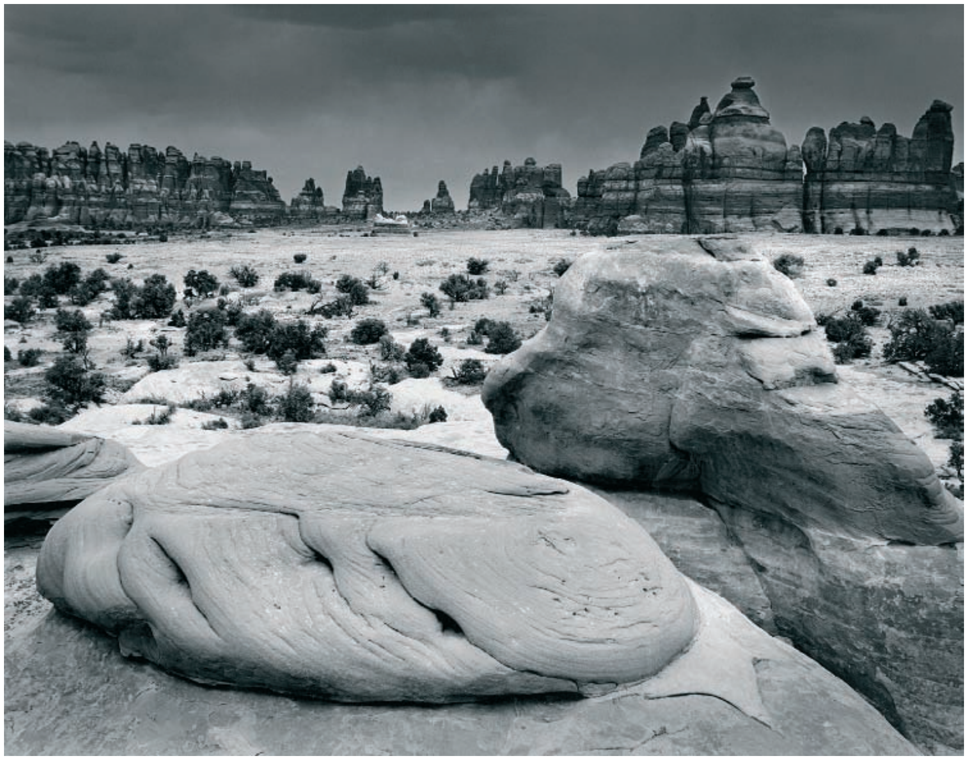


fig.11 Storm Over Chesler Park, 1977 - Canyonlands National Park, Utah. Observing a threatening thunderstorm in remote Chesler Park, I waited nearly two hours for the light to change until it agreed with my intended image. This print was made from a sandwich of the original negative with an unsharp mask using standard dodging and burning techniques, followed by a SCIM exposure to enhance the local contrast within the deep shadows. The bright sky did not give the mood that I intended for this image, and standard burning techniques were unsuccessful.



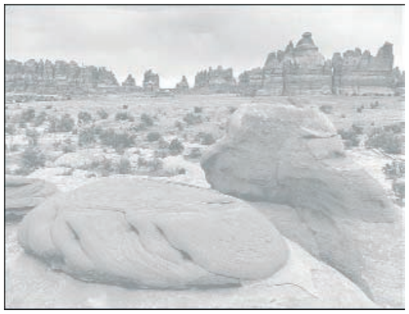
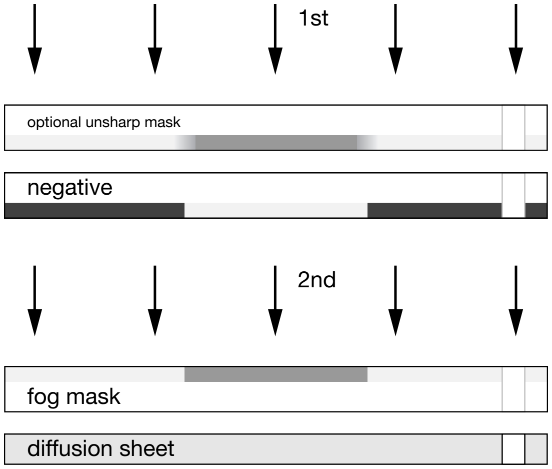


fig.12 (top) Fog Mask used in printing the final image. This is also the interpositive used to prepare the final SCIM for this image. Note that the sky is nearly clear.

fig.13 (left) Final print using the same procedures in fig.11 but also applying a Fog Mask exposure rather severely in the sky area and along the edges and bottom corners. The effect is a darkening and smoothing of the values, particularly the sky, without affecting adjacent values to a large degree. Unevenness and grain in the sky were also reduced to a great extent. I think the print successfully reveals the brooding gray mood of the scene.

fig.14 Multiple exposures are made when printing with a fog mask. The first exposure is made with the original negative and any optional masks. After the initial exposure, the negative is replaced with a sheet of textureless diffusion material and the fog mask, and a second exposure is made with this ensemble wherever a fogging effect is desired.



The following technique, using a Fog Mask, allows me to actually see the projected image on the paper, in positive form, so that I can burn or fog the highlights more accurately, using my standard burning tools, without affecting adjacent areas. I use a positive mask with a sheet of Kodak's Duratrans diffusion under the mask, sandwiched together in the pin-registration carrier, because it creates a soft, positive image projection on the paper. This allows me to burn through the clear highlight areas with non-image forming light, while adjacent darker areas are somewhat protected from excessive darkening or fogging.

### Making and Printing with the Fog Mask

Ideally, the mask used for this process has clear or nearly clear highlights, resembling an overexposed or light B&W transparency. It is a positive image on film. The interpositive that is created in the two-step Shadow Contrast Mask process is usually ideally suited for use as a Fog Mask.

Although a Fog Mask and a Shadow Contrast Mask interpositive may be one and the same, their difference lies in the printing process. After the paper is initially exposed, the original negative and any masks sandwiched with it are removed from the pin-registration carrier and replaced with a sheet of punched Duratrans or other thin textureless diffusion material on the bottom and the Fog Mask on top. The glass carrier is closed and returned to the enlarger. A burning card is held under the lens, and the enlarger light is turned on. Any desired areas can now be burned down. Keep in mind that the highlights will darken very quickly, since the clear highlight areas of the mask are doing most of the burning. The diffusion material, such as Duratrans, diffuses the edges of the Fog Mask and reduces the possibility of unwanted edge effects, which might otherwise occur on the print. I often use a softer grade filter when burning with the Fog Mask, in order to produce the smoothest fogging without any adverse line effects. A harder grade can be used to further decrease local highlight detail.

### Another Use for the Fog Mask

When I burn the edges of a print down, I attempt to create a gradual darkening toward the edges in addition to a slight reduction in local contrast. Usually, this is accomplished by burning down the edges with a softer grade. Sometimes, however, a softer grade alone is not sufficiently effective, particularly when distracting bright areas are near the edges of the print, such as in a forest scene with skylight showing through the trees. A Fog Mask is used to darken these disturbing bright areas successfully. I often burn the edges of the image first with the original negative in the enlarger. Then, I give an additional edge-burn, using a low-contrast filter and a Fog Mask/Duratrans sandwich. This effectively diminishes unwanted, distracting highlights, when done judiciously. In addition, this type of print looks comparatively richer or brighter towards the central area, due to the surrounding lower contrast and darker values.

I use a Fog Mask in the majority of my prints, particularly because it allows me to darken distracting highlights or bright areas with accurate control. It is quick and easy to make and is very forgiving of deviations in exposure and development. It is difficult to make a bad Fog Mask, because most imperfections in the mask have no adverse effects on the final print.

## The Dodge Mask

Another mask I find useful is what I call the Dodge Mask. Often, an image has many areas, varying in size and shape that I would like to lighten, and standard dodging tools and techniques do not suffice. An old remedy for this problem is what photographers call the jiggle-device.

The jiggle-device is essentially a sheet of clear glass, painted in areas needing to be dodged with red or black opaque paint. The glass is placed in a frame with bendable legs, which sits a few inches above the

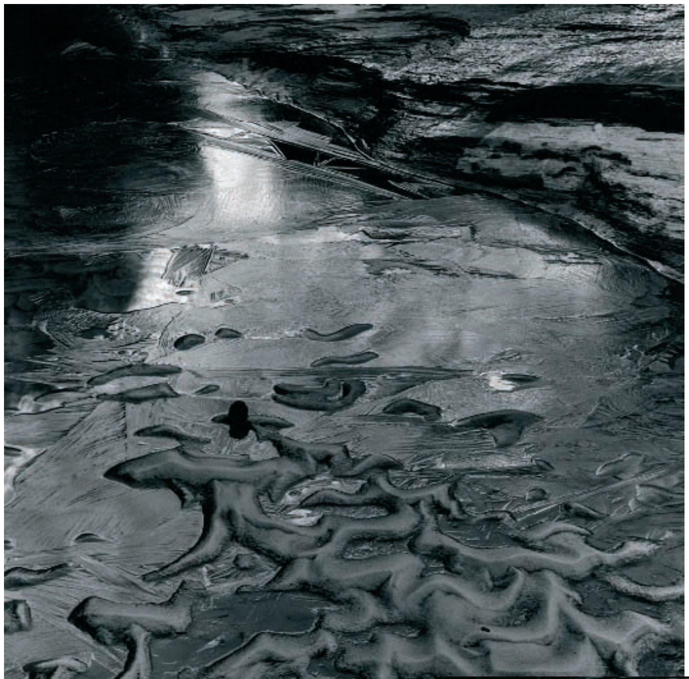


fig.15 Sand and Ice, 1986 - Zion National Park, Utah. In a remote canyon, my assistant and I came across this patch of sand mounds, still frozen from the previous brisk evening, protruding from an icy pond. This print was made using standard dodging and burning techniques. Increasing the contrast of the print with a higher-grade paper helped to separate the highlight detail to some degree, but it also caused certain details to conflict with the sand ripples. Early prints were made using a jiggling dodging device, which lightened the ripples of sand, but consistency and ease of use were always an issue. An alternative, which enables consistent results, was to use a Dodge Mask.

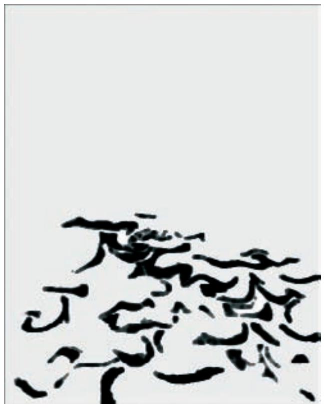


fig.16 (top) The actual Dodge Mask was made by drawing with a marking pen on a pin-registered overlay of clear film placed on top of the original negative.

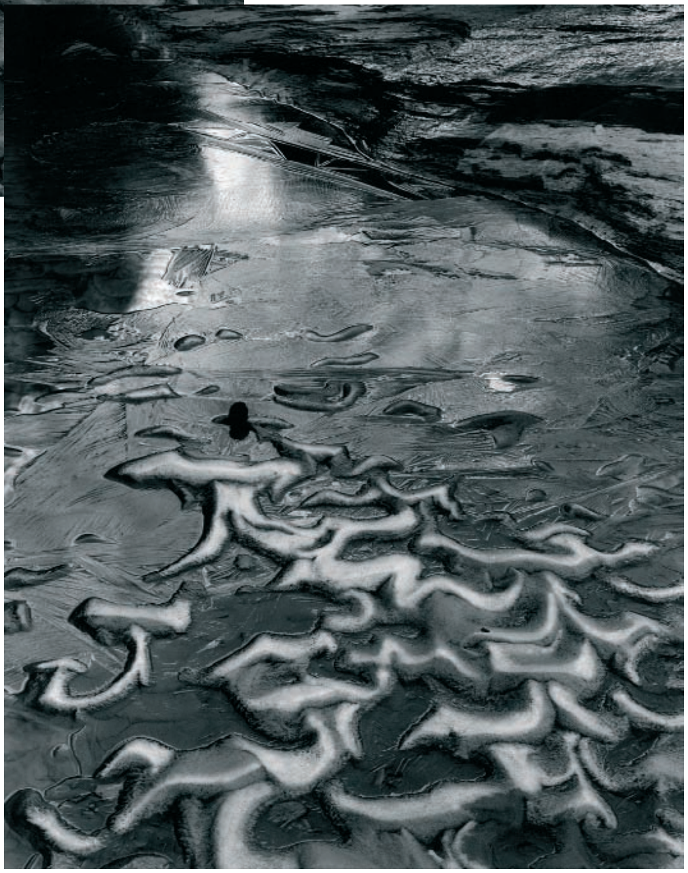


fig.17 (right) Final print made with the use of a Dodge Mask. Note that the mask lightened the sand ripples, without increasing the local contrast in the ripples. This provided precisely the effect I wanted and visualized. In a sense, this method is akin to complex dodging which would otherwise be exceedingly difficult, if not impossible.

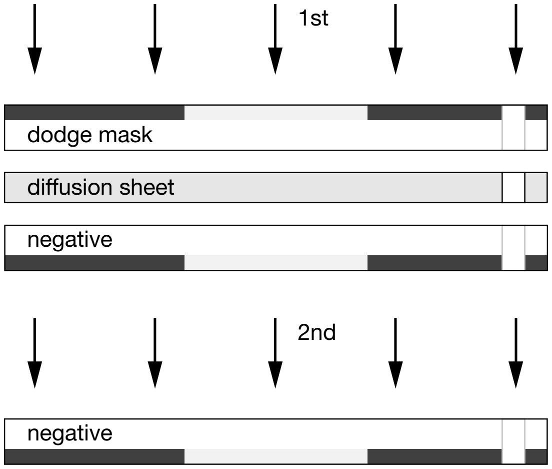


fig.18 Printing with a Dodge Mask. A pin-registered glass carrier must be used for this technique. The first exposure on the paper is made using a sandwich of the original negative on the bottom, a sheet of textureless diffusion film on top of that and the dodge mask on top of the entire assembly. A portion of the printing exposure is given to the paper, then the mask and diffusion film is removed, and the remaining exposure is given to the paper with only the original negative in place.

photographic paper. The paper is exposed in two parts. It is first exposed with the image projected through the glass, which is aligned so that the opaque areas correspond with the same areas of the negative projecting through it. During the exposure, the glass is gently jiggled, in order to soften the edges of the dodged areas. The glass is then removed and the remaining exposure is made. The process works well, but is cumbersome and does not yield repeatable results.

A more accurate and repeatable method is to use a Dodge Mask. This technique is similar to what is termed dye-dodging in that the photographer paints on a clear sheet of film, which is then placed in register with the underlying negative. This technique is best suited for 4x5 or larger negatives.

### Making the Dodge Mask

To make a Dodge Mask, the original negative is placed emulsion-side down on either a light table or an open registration carrier and held in registration pins. A sheet of clear unexposed film (litho film works well) is punched and placed on top of the original negative using the same registration pins. Kodak's Red Opaque or a black marking pen are used to draw on the clear film itself, filling-in the areas to be dodged, and being careful not to extend beyond the edges of the underlying subjects. When dry, the mask is ready for use.

### Printing with the Dodge Mask

Printing with this mask requires a two-step exposure. For the first exposure, place the original negative in the glass carrier, next to a sheet of Duratrans or other thin textureless diffusion material, then the Dodge Mask painted side up on the top of the assembly. Close the glass carrier and place the three-part ensemble in the enlarger. The first exposure holds back all the light in the opaque areas. After the first exposure, remove the carrier from the enlarger and remove the Dodge Mask and Duratrans from the carrier. Replace the carrier, which now contains only the original negative, back in the enlarger and continue the printing exposure. Obviously, several tests are needed to find the appropriate balance of the two exposures.

### A Printing Variation of the Dodge Mask

An interesting variation to consider when printing is to use a Dodge Mask as a Fog Mask. The Dodge Mask is used to pre-expose the print prior to the base exposure. When printing, the initial paper exposure is made with a sandwich consisting of a sheet of Duratrans on bottom and the Dodge Mask on top in the registration carrier. The original negative is not used during this first exposure. A very slight exposure is given to the paper through this Dodge Mask and Duratrans sandwich. In essence, the paper is flashed with non-image forming light. However, the opaque areas of the Dodge Mask dodge the light from this flash exposure.

After this initial exposure with this sandwich, the carrier is taken out of the enlarger and the contents replaced with the original negative only (or original negative with any desired mask). The base exposure is then made as usual. The resulting areas protected from the flash exposure will appear bright, and other areas affected by the pre-exposure are subdued in brightness. This is an effective way to comparatively brighten certain elements, such as bushes, while darkening competing highlights.

This flashing method has some benefits over print mask flashing techniques, which requires making a mask by hand to fit the final print size. Therefore, if the photographer wants to change the print size of a particular image, he or she must remake the mask to match the intended print dimensions. Using the Dodge Mask, however, the mask is placed in the negative plane and not the print plane, thereby allowing the photographer limitless print-size capability without the necessity of making or hand-registering new masks to suit the final print size.

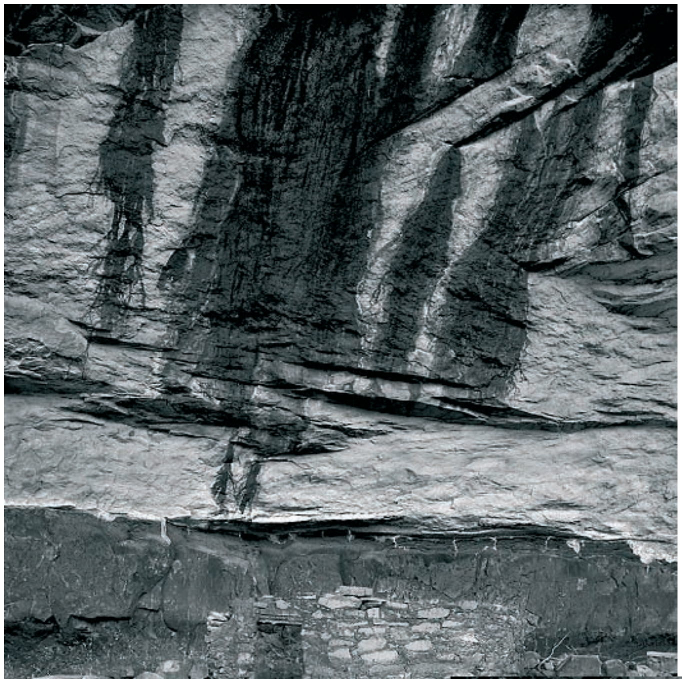


fig.19 Horse Collar Ruin, Natural Bridges National Monument, Utah. Unfortunately, the Indian ruin has little local contrast and merges into the background rock values.

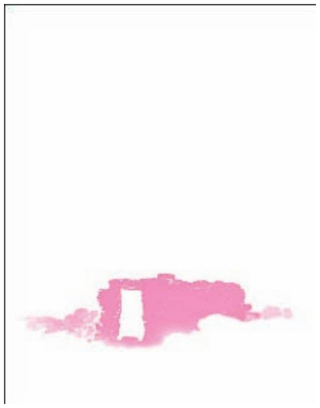


fig.20 (top) To create an inkjet dodge mask the Indian ruin is printed in magenta onto clear film. Sandwiched with the negative, the mask will brighten and increase the contrast within the ruin and separate it from the merging background rock values.

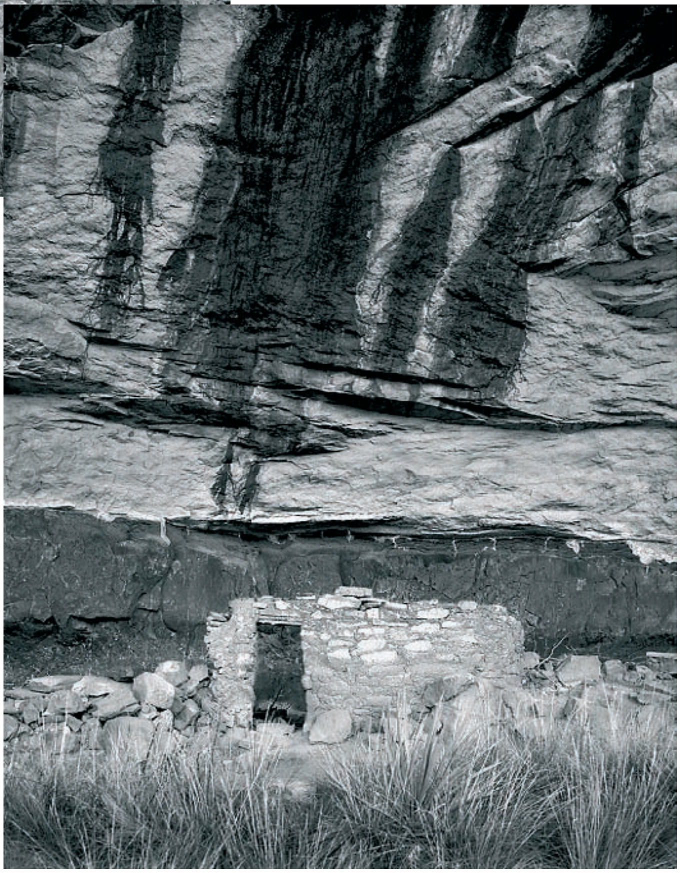


fig.21 (right) The inkjet dodge mask brightened and separated midtones and highlights selectively for the Indian ruin and nearby boulders. The effect is similar to using a highlight mask, but in this case, the inkjet dodge mask was much easier to implement. The merging values between Indian ruin and background rock would be difficult to define and isolate in a highlight mask.

## The Inkjet Dodge Mask

A computer can be used to make a more accurate form of dodge mask. Similar to dye dodging, and similar to handmade pencil or opaque masks, the use of the computer allows the photographer to create a remarkably accurate and detailed dodge mask, complete with the advantages of using different colors to achieve different local contrast effects.

A scanner is needed to create a digital file of the negative that needs masking. I standardize on a scanning resolution of 300 dpi and scan my negatives at 100% size using the color mode. With an image manipulation program, such as Adobe Photoshop, the areas that you wish to dodge must be selected and isolated from the rest of the image. Once a detailed selection of the specific areas is achieved, the next step is to fill the selection with 100% density using a color of your choice, depending on what kind of local contrast effect you are after.

To keep things simple, there are three basic color choices: yellow (to reduce local contrast), red (to dodge without altering local contrast – similar to using typical dodging methods) or magenta (to increase local contrast). After filling the selection with color, invert the selection and hit the delete key to clear the contents. Deselect, leaving only the local areas of color, which will be used to dodge the corresponding areas of the image (see fig.20).

At this point, the image must be sized to obtain a close to perfect fit when registered with the original negative. Using your inkjet printer, set the driver to use only black ink (to save ink during the sizing calibration process) and make a print of your file on plain paper. On a light table, place the printed paper image over your original negative and check to see if it matches in size. If it doesn't, continue testing by changing the image size parameters until you obtain a digital image that is the same size as your original negative. This may require a bit of experimenting and several tries.

The final step is to make your inkjet dodge mask on a transparent inkjet material, such as Pictorico's OHP inkjet film, using your printer's color mode. Some tweaking of the mask densities can easily be done by altering the colors in specific areas, by dodging or erasing areas, or by feathering or blurring edges anywhere in the mask image.

Once you achieve a good dodge mask, you should ideally pin-register it by eye with the original negative. Once registered, it can be stored separately from the original negative and re-used at any time in the future without the need to re-register it. A glass carrier is recommended when printing the negative-dodge mask sandwich, and a sheet of thin, textureless diffusion material, such as Kodak Duratrans, must be used in between the mask and the original negative when printing in order to diffuse the otherwise detectable ink dots of the mask.

In this chapter, I have shown you some basic masking techniques, and I am sure you will find ways of combining and modifying these masks to get the most from your negatives. Additional and more detailed information can be found in my Contrast Masking Kit and on my website.

Lynn Radeka's professional photography career spans nearly forty years. He has traveled and photographed the American landscape extensively since the late 1960s, making the nation's West and Southwest his forte. His B&W photography is currently featured in eight National Park posters and is represented by several galleries throughout the United States and Europe. Lynn Radeka teaches several workshops throughout the year, and his photographic work is showcased in his books: *Ghost Towns of the Old West*, *Historic Towns of America*, *Forts and Battlefields of the Old West*, *Legendary Towns of the Old West* and *Great American Hotels*. He is also the inventor and sole source of several photographic tools, including the Contrast Masking Kit and the Precision Pin-Registration Carrier System.

www.radekaphotography.com

# Digital Negatives for Contact Printing

## Analog and digital combined to hybrid halftone printing

For the most part, I favor the distinctive attributes of analog photography and, hence, prefer to work in the darkroom. But, there are some advantages to digital imaging that cannot be ignored by even the most diehard of film enthusiasts. The option and flexibility to take a digital image and easily make the necessary tonal corrections, or dramatically manipulate its composition and contents, does either not exist or is only difficult to achieve in a purely analog environment. Still, some photographers just do not want to give up on the unique qualities of an analog, fiber-base print. The reasons are mostly subjective in nature, because a well-made fiber-base print is clearly in a class of its own and truly 'beautiful'. But sometimes, the reasons to opt for a fiber-base print may be based on a specific customer request, or they simply serve as a trademark to be clearly distinguished from competing photographers. Nevertheless, there is no longer a compelling reason to make an either-or decision between analog photography and digital imaging, based on the desire to have a fiber-base print as the final output, because analog and digital techniques are easily combined. Through use of hybrid halftone printing, time-proven materials and digital image manipulation are successfully incorporated, and the final product is a fiber-base print, which is impossible to distinguish from its analog counterpart.

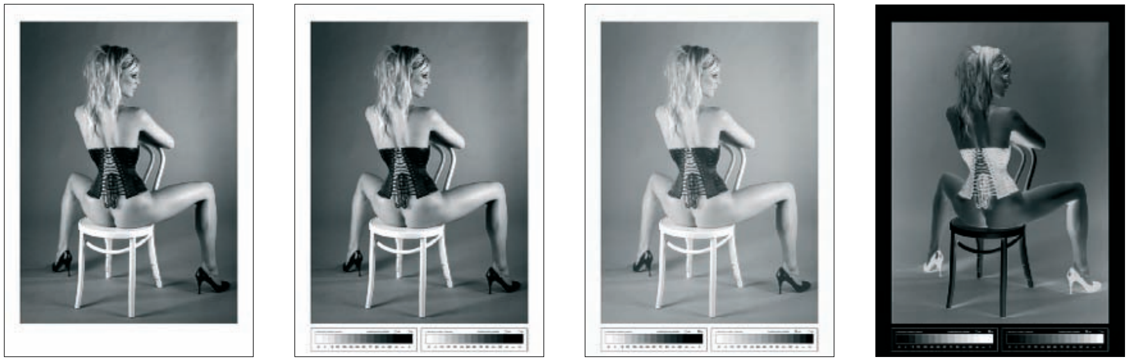
### Process Overview

Hybrid halftone printing starts with digital image data, which is first transformed into a 'digital negative' by using image manipulation software and then printed onto clear film. The digital negative is contact printed onto photographic paper and chemically processed in a conventional darkroom.

The origin of the digital image data is of no consequence to the process. The image data might come

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50035-1

fig.1 Before a digital negative can be produced, the image has to be prepared for it through several process steps.

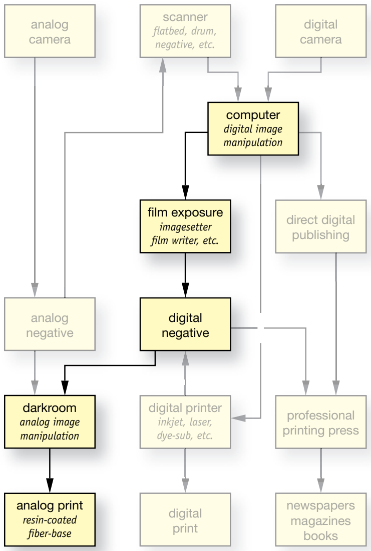


a) manipulate image and fix canvas size

b) add process controls

c) apply transfer function

d) invert image



The imaging path of the digital-negative process bridges the gap between digital manipulation and analog processing.

**Digital Image Preparation in Brief**

1. Adjust Tonal Values
2. Set Image Resolution
   Set Image Size
3. Correct Image Sharpness
4. Fix Canvas Size
5. Add Process Controls
6. Apply Transfer Function
7. Invert Image and Save Data

directly from a digital camera, or indirectly from a scanned analog negative or print. However, with the aim of contact printing, the digital negative must be of the same dimensions as the final print. In order to prepare the image data and turn it into a digital negative, image manipulation software, such as Photoshop, is used to adjust, customize and invert the image. The actual digital negative is then produced by a professional service bureau, which will use a high-resolution imagesetter to expose the image data onto clear photographic film. These machines are still used for analog printing processes, and a good offset printer in your area will help you find a local source. A digital negative differs from an analog negative only through the fact that not all image tones are continuous but are simulated through a sophisticated and imperceptible halftone pattern (see fig.10). The hybrid halftone printing process is completed in the darkroom, where the digital negative is contact printed onto light-sensitive photographic paper, after which, all remaining process steps are identical to conventional, analog photographic processing.

The cost of a digital negative depends on its size and is approximately $10-15 for an 8.5x11-inch (DIN A4) or $15-25 for a 12x16-inch (DIN A3) print. These are average prices for 'films', as they are referred to in offset printing, but unfortunately, some service bureaus charge much more, as soon as they discover the photographic intent. In that case, just make sure to simply ask for a film and not a digital negative. Store your digital negatives in traditional large-format sleeves, in a cool and dry place, alongside your other analog negatives.

## Digital Image Preparation in Detail

After opening the data file in Photoshop, the image is first improved for its pictorial impact. This includes giving emphasis to essential image content, all burn-in exposures and retouching of image flaws. In other words, in hybrid halftone printing, typical photographic improvements are transferred from the darkroom to the software and carried out only once for each negative, and not again and again for each print. Afterwards, the image is prepared for output to an imagesetter. Since the required process steps are the same for every negative, it is straightforward to list and explain them by means of an example (fig.1).

### 1. Adjust the Tonal Values

Digital negatives are always monochrome, which is why the image data is immediately converted into this mode (Image > Mode > Grayscale). This reduces the amount of data to a minimum without losing any image detail. On the other hand, special care needs to be taken that subtle highlights and shadows do not become too light or too dark, respectively. There is a risk that extreme tonal values are otherwise lost in the image transfer process from digital image, through digital negative to fiber-base print. To prevent this from happening, the image data is adjusted up to a point where the brightest highlights are not brighter than 4% and the darkest shadows are not darker than 96% (Image > Adjustments > Curves...). At this point, all tonal manipulations are completed, and if the image is still in 16-bit mode, it can be safely reduced to 8 bit now, since this is sufficient to represent up to 256 different shades of gray (Image > Mode > 8 bits/channel).

### 2. Set Image Resolution and Size

To produce quality halftone negatives, digital images of relatively high resolution are required. Consequently, I recommend an image resolution of 450 ppi. Since the final negative size is known, in this example DIN A3, we can specify the image resolution and size together in one operation (Image > Image Size...). To have the benefit of a border around the image, make sure that the image dimensions are about 40-60 mm smaller than the DIN-A3 canvas (297 x 420 mm) itself, and resample the image data, using the bicubic option in Photoshop, which will minimize the side effects of extrapolating image data (fig.2a).

### 3. Correct Image Sharpness

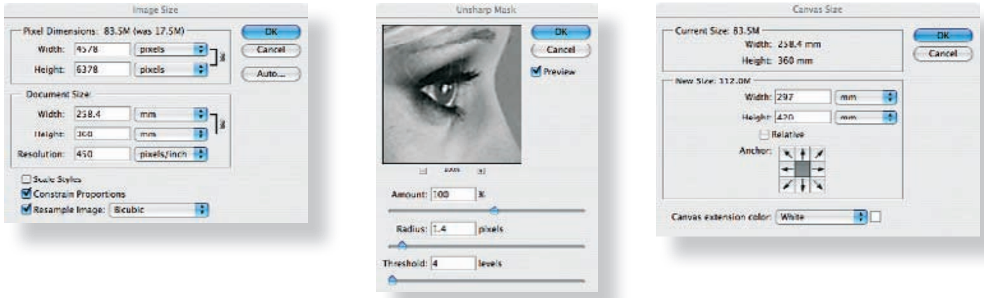
After the image is set to the final dimensions, it may be necessary to correct the overall image sharpness. Photoshop's unsharp filter is an excellent tool to do so (Filter > Sharpen > Unsharp Mask...). Acceptable image sharpness depends heavily on personal preference, but with this powerful filter, it is easily overdone. To maintain a realistic-looking image, the settings in fig.2b are recommended as a starting point for digital negatives.

### 4. Fix the Canvas Size

We need to expand the canvas now in order to match the DIN-A3 format (Image > Canvas Size...). This is done symmetrically on the horizontal axis, but in the vertical direction, it is to our advantage if we leave a wider border below the image than above it. This provides the necessary space to add two process controls in the next step. Nevertheless, final image placement on the canvas is not overly important and also depends on image size (fig.2c). At this point, our new canvas should look very similar to the example in fig.1a.

### 5. Add Process Controls

This is an optional but highly recommended step when preparing a digital negative. Add two process controls, by opening a reference file and placing it twice, side by side, below the image. This reference file is called 'ProcessCheck.tif' and is available from my website at no cost (fig.3). It is designed as a step tablet and is used to easily verify significant process parameters. With the aid of a densitometer, the step tablet on the left is used to confirm correct exposure and development of the film at the service bureau.



Pixel Dimensions: 83.5M (was 17.5M)
Width: 4578 pixels
Height: 6378 pixels
Document Size:
Width: 258.4 mm
Height: 360 mm
Resolution: 450 pixels/inch
☐ Scale Styles
☑ Constrain Proportions
☑ Resample Image: Bicubic

☑ Preview
Amount: 100 %
Radius: 1.4 pixels
Threshold: 4 levels

Current Size: 83.5M
Width: 258.4 mm
Height: 360 mm
New Size: 312.0M
Width: 297 mm
Height: 420 mm
☐ Relative
Anchor:
Canvas extension color: White

a) Image resolution and size are specified together with 'Image Size'.

b) Image sharpness is corrected with 'Unsharp Mask'.

c) The final digital negative dimensions are defined with 'Canvas Size'.

fig.2 Subsequent to artistic image manipulations and adjustment of tonal values, it takes three more steps to specify image resolution and size, to correct image sharpness and to define the final digital negative dimensions.

The step tablet on the right is a useful guide to determine the best exposure and contrast in the darkroom. Depending on image size, it may be necessary to adjust the scale of the step tablet in order to fit it in twice below the image. While doing so, be sure to keep the tablets and image resolution identical. After placing both step tablets, reduce all layers to one (Layer > Flatten Image). Following that, the canvas should look like the example in fig.1b.

### 6. Apply the Transfer Function

Most photographic processes are nonlinear, or in other words, the relationship between their input and output is not proportional. As an example, doubling the film exposure does not necessarily double the transmission density of the negative. During hybrid halftone printing, all image tones are transferred from the digital image, through the digital negative to the fiber-base print. Through careful selection of exposure and contrast, it is not difficult to control the highlight and shadow endpoints to prevent a loss of detail at the extremes of tonality. However, all remaining tonal values are forced to follow material characteristics alone and fall predictably somewhere in between the endpoints of tonality. In order to achieve a close match between on-screen image and final print, it is important that the influence of these material characteristics are compensated through the use of a transfer function. Applying such a function is easy, and creating a transfer function only needs to be done once, but it does involve a few additional steps. That is why we added a chapter with detailed instruction to the appendix and called it 'Make Your Own Transfer Function'.

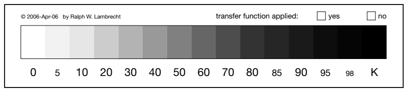

© 2006-Apr-06 by Ralph W. Lambrecht
transfer function applied: ☐ yes ☐ no
0
5
10
20
30
40
50
60
70
80
85
90
95
98
K

fig.3 'ProcessCheck.tif' is an optional process control to monitor exposure and development at the service bureau and in the darkroom.

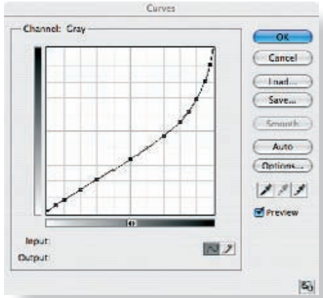


fig.4 Nonlinear photographic processes are controlled through a compensating transfer function.

**Transfer Function Example**

(monitor γ = 2.2 > imagesetter > MGIV-FB)

| Input | target density | Output at |
|---|---|---|
| 0 % | 0.05 | 2 % |
| 5 % | 0.11 | 5 % |
| 10 % | 0.16 | 9 % |
| 20 % | 0.27 | 15 % |
| 30 % | 0.38 | 21 % |
| 40 % | 0.51 | 27 % |
| 50 % | 0.66 | 33 % |
| 60 % | 0.83 | 40 % |
| 70 % | 1.04 | 47 % |
| 80 % | 1.30 | 56 % |
| 85 % | 1.45 | 62 % |
| 90 % | 1.63 | 69 % |
| 95 % | 1.84 | 81 % |
| 98 % | 1.99 | 90 % |
| 100 % | 2.10 | 100 % |

**Overview of Work Instructions for the Service Bureau**

1. Order a typical 'film' as it is used in analog pre-press work for offset printing.
2. Ask for an imagesetter resolution of at least 3,600 dpi.
3. Demand a halftone screen ruling of 225-300 lpi.
4. Request the film to be made emulsion-side up but imaged right-read, which means no image flipping or mirroring.

The transfer function is not applied to the entire canvas. The step tablet on the left serves only to verify the service bureau's film quality, and must, therefore, be excluded from the transfer function. This is done by first selecting the left step tablet, and immediately inverting this selection again (Select > Inverse). As a result, everything but the left step tablet is now selected. The appropriate transfer function is activated through the curve menu (Image > Adjustments > Curves... > Load...). For this example, I have chosen a transfer function that was specifically developed for Ilford's Multigrade IV FB (see fig.4 and text box on the left). Once the transfer function has been applied, the entire selection is turned off (Select > Deselect). At this point, our canvas should look similar to fig.1c, which in many cases may not look right at first sight. But, that is no reason for concern, because it just illustrates how much image tonality needs to be skewed in order to compensate for the subsequent nonlinear reproduction of tonal values.

**7. Invert the Image and Saving the Data**

So far, we have worked exclusively with the image positive, but obviously, contact printing requires a negative. Photoshop makes this conversion as simple as possible (Image > Adjustments > Invert). This concludes the digital image preparation, and the only step left is to select an appropriate data storage format and medium for storing the digital negative.

Many image data formats, including jpg, are good options for storing digital negatives, but I recommend using the lossless Tagged Image File Format (tif). Don't compress the file, and don't attach a color profile to it. Professional service bureaus are most accustomed to tif data, and color-management features are often incompatible with their imagesetter software. High-resolution negatives, for DIN-A3 or 11x14-inch print formats, easily require 40-60 MB of memory, which makes a compact disk (CD) an economical and convenient choice for transferring and storing several negative files.

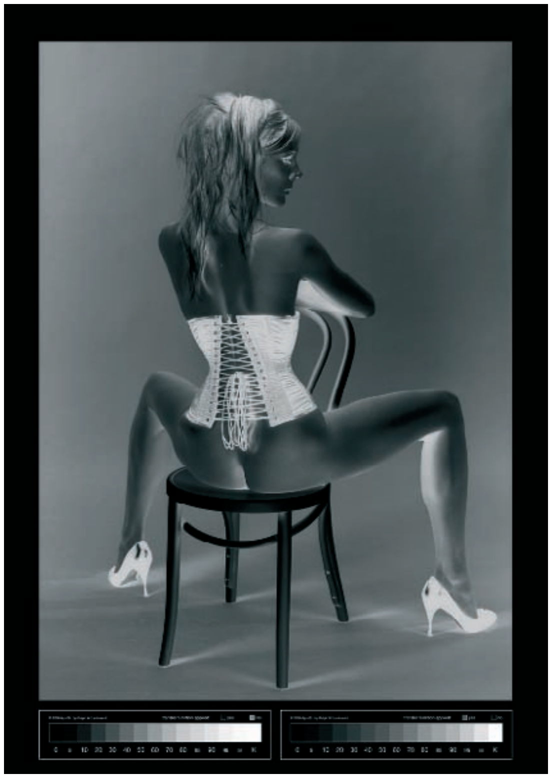


fig.5 There is no physical difference between analog and digital negatives. Both have a transparent base that is coated with a silver-gelatin emulsion. However, the formation of continuous image tones is very different between the two.

## Digital Negatives from Imagesetters

We leave the exposure and actual production of the physical digital negative to a professional service bureau. They use a raster image processor (RIP) to convert the digital image to a half-tone bitmap and send the data to an ultra-high resolution printing device, called an imagesetter, where a piece of high-contrast film is exposed by a laser. This film is then developed, fixed, washed and dried to produce a digital negative for contact printing.

There is little physical difference between analog and digital negatives. Both have a transparent base that is coated with a silver-gelatin emulsion. However, the formation of continuous image tones is very different between the two. In an analog negative, image tones depend on negative density, which in turn is directly related to how many microscopically small silver particles have randomly accumulated in a specific area. This allows for almost perfect continuous image tones. In a digital negative, on the other hand, continuous tones are only simulated through a complex bitmap halftone pattern, which mimics the equally spaced

**Glossary of Abbreviations**

**dpi** *(dots per inch)*
Printers reproduce text and images by marking film or paper with numerous dots of ink or light. Printer resolution is measured in dpi.

**lpi** *(lines per inch)*
Grouping several dots into a halftone cell provides the potential of simulating many different shades of gray. Halftone cells are organized in line screens, and their resolution in measured in lpi.

**ppi** *(pixels per inch)*
Monitors display text and images through tiny pixels. Monitor resolution is measured in ppi.

**spi** *(samples per inch)*
Scanners, scanning backs and digital cameras detect image and print detail in fine increments and record them as image samples. The resolution of image-capturing devices is measured in spi.

*To use the processing steps of hybrid halftone printing as an example, one would say:*
*An image was recorded by a scanner or digital camera with 300 spi, then displayed on a monitor with 300 ppi, extrapolated by Photoshop to 450 ppi in order to rasterize it with a 225-lpi halftone screen and print it on film with a 3,600-dpi imagesetter.*

dots of varying sizes, used for conventional halftone printing. This does not allow for a truly continuous-tone image, because only a limited number of gray tones can be created this way, but the increments can be kept so small that tonality boundaries become imperceptible to the human eye.

The resolution of a halftone pattern, also called 'halftone screen ruling' or simply 'halftone screen', is measured in lines per inch (lpi). Newspapers, which use halftone patterns to simulate photographs, use a rather coarse halftone screen of about 85 lpi, which is easily detectable by the naked eye. High-quality magazines make use of much finer halftone screens of up to 133 lpi, which makes it much harder to detect the pattern. For digital negatives, an extremely fine halftone screen of 225-300 lpi is used to simulate continuous tones, approaching the quality and fine graduation of analog photographic prints. This is roughly equivalent to 6-9 lp/mm, and even with perfect eyesight, such a fine halftone pattern cannot be detected without the aid of a loupe.

## Contact Printing

In the darkroom, the digital negative is positioned, emulsion-side up, onto photographic paper and both are securely and tightly held together in a contact frame. If such a frame is not available, the weight of a thick sheet of glass (1/4 inch or 6 mm) is usually sufficient to press negative and paper gently together (fig.6). For larger prints, light clamping around the edges may be necessary to ensure that they are in contact across the entire surface.

Subsequent exposure and paper processing are identical to analog contact printing, because the same fiber-base materials are used for hybrid halftone printing. This also means that the halftone print can be chemically toned to add to its life expectancy; it can be retouched, dry-mounted, presented and stored like any other analog fiber-base print.

Contact printing the digital negative with the emulsion-side up brings the film emulsion in direct contact with the glass, and separates emulsion and paper by the film thickness. This minimizes the formation of Newton's rings and causes some light scattering in the film base during the print exposure, which has advantageous consequences. The scatter is strong enough to diffuse the halftone pattern somewhat, but it's too small to produce a detectable loss of image sharpness (fig.7). In other words, if the digital negative is printed emulsion-side up, the simulation of continuous tones is improved without a detrimental effect on overall image quality. Also, a diffused halftone pattern is more responsive to paper-contrast manipulations, which the halftone image is largely resistant to, if printed emulsion-side down.

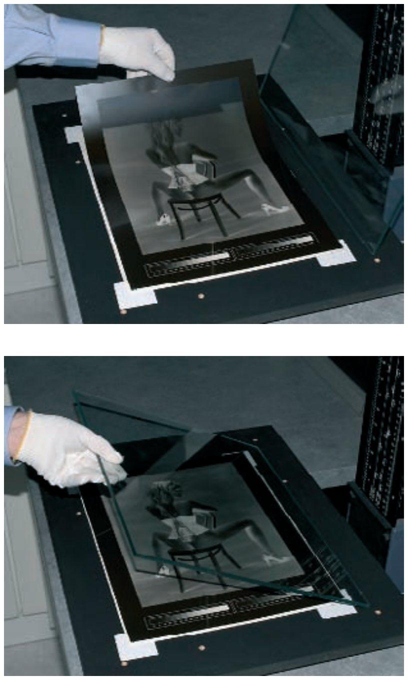


fig.6 In the darkroom, the digital negative is positioned, emulsion-side up, onto the paper and both are tightly held together by the weight of a thick sheet of glass. Subsequent exposure and paper processing are identical to analog contact printing.

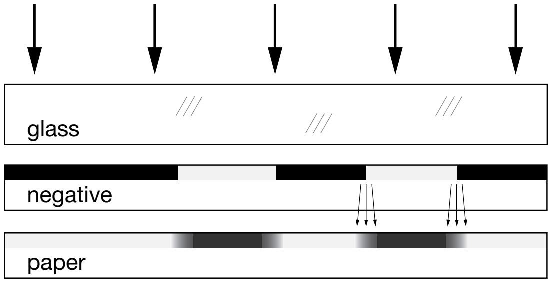


fig.7 Contact printing the digital negative emulsion-side up causes some light scattering and a welcome loss of clarity in the halftone pattern, without a loss of image sharpness. It also makes the halftone image more sensitive to skillful paper-contrast manipulations.

### Exposure

Determining the ideal exposure for the hybrid print is greatly simplified by utilizing the right step tablet as an aid and process control. This step tablet was customized through the transfer function, and hence, it contains all required tonal values in smooth increments.

First, the enlarger light filters are set to a normal paper contrast of grade 2. Then, while making test strips of the step tablet, an exposure time is established at which step 0K still maintains paper white, but step 5K clearly shows the first signs of density.

Once the ideal exposure is found, record all enlarger settings and refer to them for other hybrid printing sessions. This can be done, because digital negatives have a very consistent density due to tightly controlled processes at the service bureau. This process stability can be alternatively checked, measuring the left step tablet with a densitometer before printing a digital negative for the first time.

### Contrast

Well-designed transfer functions allow creation of digital negatives that easily print on normal-grade paper without the need for further manipulation. Nevertheless, there are always small process-dependent deviations while working in the darkroom, and to compensate for them, moderate contrast adjustments are sometimes necessary. Remember that halftone images are not very susceptible to paper-contrast changes. It will often take modest increments to see minute affects. Nevertheless, the ideal paper contrast is determined through a second test strip, using the ideal exposure found above, but altering the contrast until steps 95, 98 and 100K are still distinguishable from each other. Optimizing print exposure and contrast ensures that all tonal values, captured in the digital negative, are fully represented in the final hybrid print.

## About Halftones

The history of halftone printing dates back to 1850, when William Fox Talbot suggested using ‘screens’ in connection with a photographic process. Several screen designs were proposed, but it took until 1880 for the first reproduction of a photograph to be published in the *New York Daily Graphic* by Stephen H. Horgan. Shortly after, in 1881, the first successful commercial implementation was patented by Frederick Ives. Prior to his invention, newspapers and magazines could not be easily illustrated with photographs, because publishers were limited to woodcuts, engravings or etchings, in order to include images into the printing process. Ives’s method, still in use today, was the first not limited to printing just black or white, but made it possible to reproduce all shades of gray. In 1992, Dan Burkholder rediscovered halftone printing for B&W photography, by using offset printing films as contact negatives. In 1995, he published his technique in a book called *Making Digital Negatives.*

Analog halftone printing is a reprographic technique that simulates continuous-tone images through equally spaced dots of varying sizes. In digital halftone printing, this is accomplished by

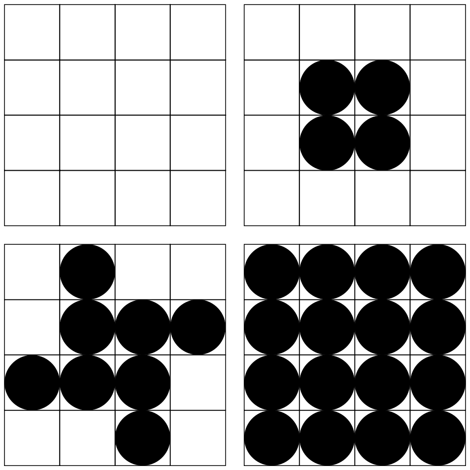


fig.8 Grouping several dots to a cell provides the potential of reproducing many different shades of gray. By printing none, all, or only specific dots of a 4x4 halftone cell, 16 shades of gray plus white can be simulated. A 12x12 matrix can represent 144 shades of gray, and using a 16x16 matrix allows for 256 different grays, which are more than the human eye can possibly differentiate in a photograph.

$$\text{shades of gray} = \left(\frac{\text{printer resolution}}{\text{halftone screen}}\right)^2$$

$$\text{halftone screen} = \frac{\text{printer resolution}}{\sqrt{\text{shades of gray}}}$$

$$\text{printer resolution} = \text{halftone screen} \cdot \sqrt{\text{shades of gray}}$$

$$\text{image resolution} = \text{halftone screen} \cdot \text{quality factor}$$

$$\text{quality factor} = 1{,}5 - 2{,}0 \quad (\text{good - better})$$

fig.9 halftone mathematics

creating varying bitmap patterns through equally spaced halftone cells. A single dot only represents one of two conditions; it either exists (black), or it does not (white). However, grouping several dots to a cell, organized as a matrix in rows and columns, provides the possibility of reproducing many different shades of gray. Fig.8 shows four halftone cells, all of which consist of the same 4x4 matrix of printing dots. By printing none, all, or only specific dots, a halftone cell of these dimensions can simulate 16 shades of gray plus white. A 12x12 matrix can represent 144 shades of gray, and using a 16x16 matrix allows for 256 different grays, which are more than the human eye can possibly differentiate in a photograph.

Unfortunately, combining several small printing dots, in order to form larger halftone cells, reduces the available image output resolution. To make things worse, the technique can only be successful if the cells are small enough, or seen from a sufficient distance, for the halftone pattern not to be resolved. Halftone screen rulings of 225-300 lpi satisfy this requirement, but this calls for relatively high digital image and printer resolutions. The image resolution depends on individual quality requirements and must be 1.5-2x higher than the halftone screen. The printer resolution, on the other hand, depends on the required shades of gray and must be 12-16x finer than the halftone screen. Fig.9 shows the mathematical relationships involved, which can be easily illustrated through the following examples.

Let's assume that our service bureau is using an imagesetter with a maximum printer resolution of 3,600 dpi. If we prefer a very fine halftone screen of 300 lpi, we will be limited to 144 shades of gray. However, if we require 256 shades of gray, we are forced to reduce the halftone screen to 225 lpi. If we demand both, we need an imagesetter with a printer resolution of 4,800 dpi. And, using a 225-lpi screen, we can expect to get the best halftone print possible, if our digital image has a resolution of 450 ppi.

The development of the ideal halftone pattern for each cell is a rather complex mathematical task. We gladly leave this chore to the service bureau and their Raster Image Processor (RIP). It's our job as photographers to make sure that we maintain the correct digital image resolution, and that we provide the service bureau with all the data they require to produce a high-quality digital negative for us. Then, we will finish our hybrid halftone prints in our darkrooms, just as we do with our analog prints.

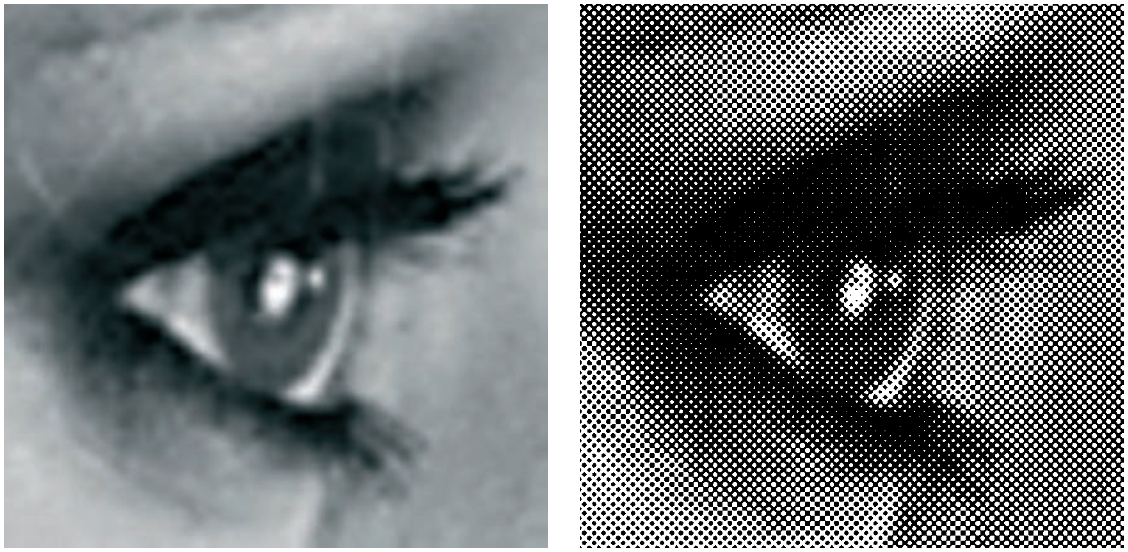


fig.10 These close-ups represent roughly 12x magnifications of their original images. Individual pixels can easily be detected in the monitor representation on the left, and the halftone pattern is clearly visible in the hybrid halftone print on the right. Nevertheless, one can get as close as 250 mm to the original hybrid print without detecting the halftone pattern with the naked eye. In relation to these magnifications, this is equivalent to a 3-meter (12-foot) viewing distance. Try to view this page from such a distance, and see if you can detect a difference between the two images.

# The Copy-Print Process

## How to get silver-gelatin prints from inkjet positives

In 'Digital Negatives for Contact Printing', we introduced a precise and repeatable digital-to-analog process for the perceptual conversion of monitor images to photographic prints, using halftone negatives. This process has the remarkable property of being consistent between pre-press offset printers, and is also largely tolerant of paper characteristics, as well as exposure and contrast deviations. For these reasons, we are able to suggest accurate starting points for hardware calibration, which will work without modification for all readers who have access to this type of equipment or an old-style service bureau.

The recent expansion of digital printing technology has improved to a point that it competes with traditional offset printing, unfortunately resulting in fewer outlets for creating photographic halftone negatives. At the same time, consumer inkjet printers have become consistently acceptable for photographic color proofs, but their lack of performance in tonal purity, permanence, bronzing, compatibility with gloss paper surfaces and metermerism is significant enough to deter the discerning monochrome worker. These factors, together with a desire to have complete control over the reproduction process, have prompted many to consider using consumer inkjet technology on translucent media to produce large contact negatives. The limitations of inkjet technology are of little consequence when their output is used as an intermediate step on the way to a photographic print.

This is a photograph of Layer Marney Tower, a Tudor palace dating from 1520, which was taken with a Nikon D200 and an 18-55 f/2.8 DX lens while planning a wedding venue. A medium-format Mamiya 7 would have been better for this image, but I made the most of the opportunity and prepared a toned silver-gelatin print via an inkjet-printer positive.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50036-3

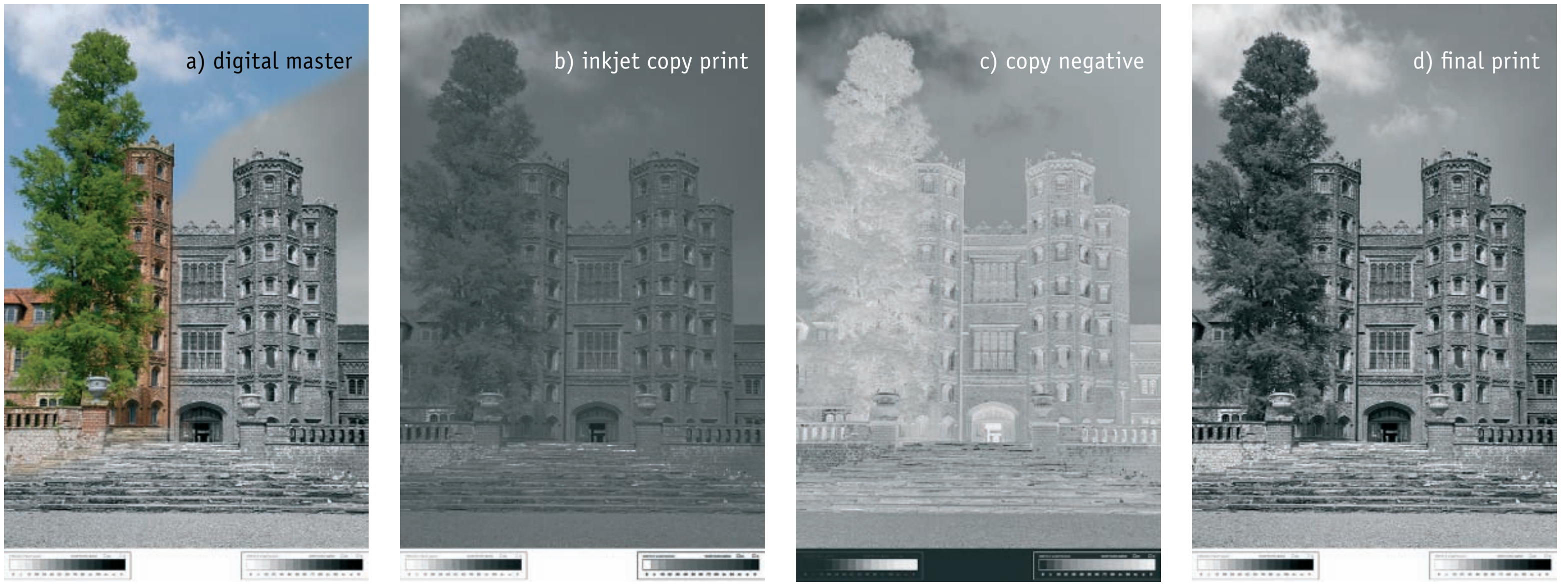


fig.1 Creating a silver-gelatin print from a digital file is done in several steps.
a) A monochrome digital master is prepared from the color original.
b) A matt inkjet copy print is made after a transfer function is applied.
c) A copy negative is made by photographing the matt inkjet copy print onto regular film.
d) The final silver-gelatin print is made from the copy negative with traditional photographic methods.

## Process Overview

It turns out that a simple copy negative, made of an adjusted inkjet print onto regular film, is a viable alternative to a halftone negative. In practice, a large inkjet copy print of a digital master image is photographed onto monochrome film and the resulting negative is conventionally enlarged onto silver-gelatin paper. Since the photographic process compresses extreme print values, it is necessary to apply a transfer function to the digital image prior to inkjet printing to cancel out these tonal distortions and faithfully reproduce the original image. The copy negative can be on 35mm, medium or large-format film, depending on the intended grain and final enlargement size. Figure 1 shows the imaging sequence of the copy-print process from digital master to final print.

### 1. Preparing the Digital Master

A digital color original is first converted to monochrome, carefully manipulated and optimized in the photo-editing software, so that the highlight and shadow values are adjusted to recommended values. To achieve the best image quality, the digital master file is acquired and remains in 16-bit mode with sufficient resolution to support the intended print size. Assuming standard vision, an 8x10-inch print requires a minimum file resolution of 280 ppi. The monochrome digital master file is saved for later use.

### 2. Making the Inkjet Copy Print

Apply the transfer function, which has been previously determined by a calibration process, to the digital master file. The adjusted image is printed onto smooth, matt inkjet paper. The printer settings must be identical to those used for the copy print during the calibration process. Best results are obtained if all color management is disabled and a suitable media setting for the paper surface selected.

### 3. Making the Copy Negative

The matt copy print is pinned to a wall and photographed onto film, after ascertaining that the camera is square-on. The light level is determined by an incident light meter, but the film is overexposed by 1 stop. Then, the film is developed in the same manner and for the same contrast as in the original calibration process, ideally N+1.

### 4. Making the Final Print

During the calibration process, an optimum print exposure and contrast setting were used to obtain a final silver print. Our copy negative is now printed with these same exposure and contrast settings. Unlike the halftone process, however, further creative expression can be introduced with global or local adjustments to silver-print exposure and contrast, just as with any conventional negative.

**The Copy-Print Process in Brief**

1. Prepare Digital Master
2. Apply Transfer Function
3. Make Inkjet Copy Print
4. Photograph Copy Print
5. Develop the Copy Negative
6. Make Silver-Gelatin Print

**Digital Master Preparation**

1. Acquire 16-bit Image
2. Adjust Tonal Values
3. Scale Image to Inkjet Paper
4. Check File Resolution
5. Correct Image Sharpness
6. Create Canvas Margins
7. Add Process Controls

## Process Optimization

Excellent print results require careful consideration of the tonal accuracy within the entire digital workflow, a robust and repeatable method for copying prints onto film and an optimized film exposure and development. Also, the resolution of the digital master and all inkjet print settings must support the required resolution of the final silver-gelatin print.

### Tonal Accuracy

Successful digital editing considers the human perception of on-screen images and the mechanical production of digital prints. Although the plan is to use the proposed rendering intent in 'Make Your Own Transfer Function', we should be aware that digital editing is influenced by the human response to the appearance of the image on the screen. Human perception is adaptable, and the response to a displayed image varies in relation to ambient light levels, surroundings and emotions. To solely use the image data to determine tonality, is not a practical solution. The data can be used to set key image tones, but it is not the most reasonable proposition to determine local contrast settings for textured areas.

Effective digital editing is done in two steps. Tonal endpoints, as well as key highlight and shadow tones, should be adjusted first, using the image data in the info palette. This is followed by global or local tonal shaping, using visual cues and relationships. Visual editing requires a monitor that does not clip highlight or shadow tones and has a defined reproduction between them. If the final print does not convey the same brightness and tonality as the screen image, feel free to adjust the proposed rendering intent and the target densities for the transfer function to create your personal rendering intent.

### Copying the Inkjet Print

On glossy and luster paper surfaces, dye-based inkjet printers can achieve remarkable reflection densities in excess of 2.4, which suggests a normal (N) development scheme for the copy negative. Unfortunately, these surfaces are difficult to copy without including unwanted reflections from surrounding objects and light sources. Fortunately, all inkjet printers also work with matt paper surfaces. This not only allows the use of pigment-based printers, but more importantly, it also removes many disadvantages, otherwise typical to copying prints onto film, including the sensitivity to unwanted reflections. Quite unlike for a standard copy setup, diffuse daylight is the most effective light source. It is feasible to copy a print with nothing more than a small mirror, a tripod, a few pieces of sticky tape, an empty wall and a large window on the opposite side. The mirror is used to ensure that the camera is square on to the inkjet print. With the mirror held flat to the wall and in the middle of the print, the camera is in the correct position when the lens appears centered in the mirror and the print fills the viewfinder.

### Exposing and Developing the Copy Negative

The maximum reflection density (Dmax) of a matt print is approximately 1.5, which makes for a 5-stop subject brightness range. Such a low-contrast subject requires an increase in film development (N+1) or a boost in paper contrast to achieve a full-bodied print. An incident light meter is used, preferably with a flat diffuser, to determine the exposure and check for even illumination. It is prudent to increase the exposure in order to correct for the unavoidable and inherent exposure loss of close-up photography, and ensure that the darkest image values are not lost.

It is worth experimenting with the N+1 development scheme in combination with 0 and +1 stop exposure compensation from the metered value. Sufficient exposure will improve shadow separation, beyond which, print grain and resolution will deteriorate. Depending on the film emulsion, a hard print contrast and a normal negative contrast may produce a more pleasing result than the reverse arrangement.

### Resolution

The copy-print process introduces two additional steps into the imaging chain with potential for resolution loss, associated with the matt inkjet print and copying it to the negative. To confirm that the resolution capability of the copy-print process is sufficient to support the requirements for the final silver-gelatin print, a high-resolution image of the USAF/1951 test pattern was printed on matt paper and photographed onto 4x5-inch Kodak Tri-X and medium-format Fuji Acros 100. The negatives were then printed at the same scale as the original test chart. In each case, short telephoto lenses were used at their optimum aperture for maximum resolution and sharpness.

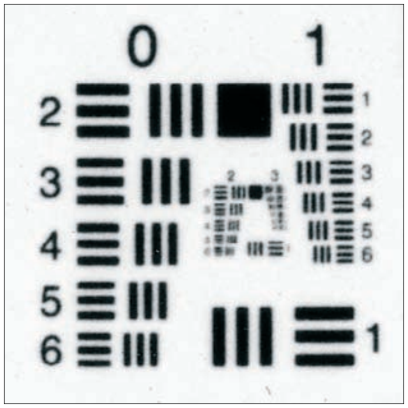


fig.2a The final print, made from the 4x5 Tri-X copy negative, achieved a resolution of 6.5 lp/mm, which is only slightly less than that of a traditional contact print.

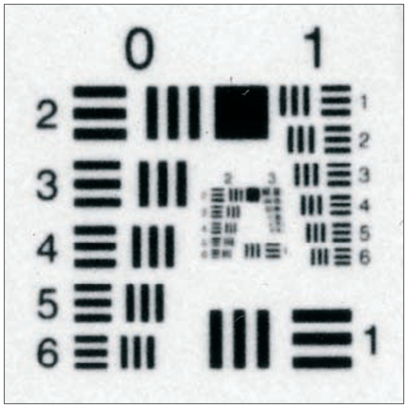


fig.2b A silver-gelatin print, made from a medium-format Acros 100 negative, achieved a similar resolution and grain structure to that of Tri-X on 4x5 sheet film.

The silver-print resolution, achieved with both films (fig.2), exceeds the required print resolution for standard observation of about 6.5 lp/mm. The Tri-X result is a little sharper, but the grain structure is similar to Acros 100, which is a result of the different enlargements required for the two formats. This represents the peak performance, and in practice, other printer hardware and image file resolution settings affect the final outcome.

### 1. Hardware Resolution

Every inkjet printer has a specific print resolution, measured in dpi, which is not to be confused with the image file resolution, measured in ppi. The image file resolution is adjustable by the user, depending on whether the image is to be being viewed on screen or as a physical print. Assuming a fixed number of image pixels, the higher the ppi setting, the smaller the printed image becomes. Some printers require a specific ppi to match their hardware dpi setting, others (principally inkjet printers), can use any image ppi, since the printer driver automatically scales the image.

Confusingly, inkjet printers spray complex patterns of ink, which defy any convenient theoretical resolution calculation (you can breathe a sigh of relief). Several ink blobs of varying intensity and sizes are required to define a single colored ‘dot’. Annoyingly, in a bid to outdo each other, print manufacturers often claim highly exaggerated resolutions that bear little relation to the actual print resolution of their products. These spurious numbers together with their complex printing algorithms, ink bleed and paper surface effects, just to form an ink dot, utterly confuse the issue. To make matters worse, many inkjet printers have higher resolution in one direction than in the other. As a result, the user can change the file ppi setting prior to printing and in some cases change the printer ‘dpi’ setting, in a printer control panel, to produce an effective dpi that matches neither number! Suffice to say, in practice, all modern photo inkjet printers achieve sufficient mechanical resolution as long as their highest hardware resolution settings are used for this process.

### 2. Image File Resolution

A relationship between the image file resolution and print resolution is required to determine the required file ppi setting. Similar to the physics of digital capture, a printer, when laying down ink on paper, requires about 67 ppi per lp/mm to assure that line pairs are printed with 50% contrast, but only 53 ppi per lp/mm to print them with 10% contrast. For example, an inkjet print can resolve 5 lp/mm in all directions using a 300 ppi file setting, confirming a similar ppi and lp/mm relationship to that established for digital capture. Fig.3 shows the measured print resolutions for various image ppi settings and 10-50% contrast. These test prints were made with a high-resolution inkjet printer, which was specified as having a fixed 2,400 x 4,800 hardware dpi setting.

If an image file has sufficient resolution for a standard print, it can be used to make larger prints by deploying the image pixels over a larger area with a corresponding reduction in print resolution, assuming a proportional increase in viewing distance.

## Making a Transfer Function

A halftone negative simulates minute tonality differences, as found in continuous-tone images, through a series of equally spaced dots of varying sizes, which makes it remarkably tolerant of variations in paper exposure and grade settings. The copy-print process, however, is not as tolerant and requires the user to make an individual calibration for each choice of material and process setting. Nevertheless, the calibration method proposed in the appendix under

| image file resolution [ppi] | print resolution [lp/mm] |
|---|---|
| 225 | 3.4 - 4.2 |
| 250 | 3.7 - 4.7 |
| 275 | 4.1 - 5.2 |
| 300 | 4.5 - 5.6 |
| 325 | 4.9 - 6.1 |
| 350 | 5.2 - 6.6 |

fig.3 During the printing process, the image file resolution is converted by the printer into the actual print resolution. The measured values, shown here, were obtained from a high-resolution inkjet printer, which are in line with our standard viewing requirements at minimum viewing distance. However, this printer is able to produce a resolution of up to 10 lp/mm.

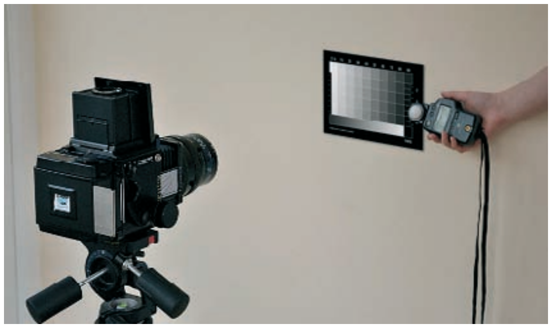


fig.4 The inkjet calibration print on the wall simulates a matt copy print to be captured onto roll-film. The camera is set up square to the wall, and the exposure is determined by an incident light meter. The same setup is used for copying the actual inkjet copy prints. Diffuse daylight is the most effective light source for copying matt surfaces. When copying inkjet prints, ensure the lens is set to its optimum aperture, and use all the available techniques to reduce camera vibration.

'Make Your Own Transfer Function' creates very accurate transfer functions for any workflow from digital image to final print. The following calibration process, outlined in the following steps, is an example of the method proposed in the appendix. It assumes a consistent darkroom operation and uniform negative and print processing, because it manipulates the inkjet copy print to account for the tone reproduction in negative and final print. The calibration compares the target densities to the actual output densities, in order to produce a close match between the on-screen image and the final print. The resulting correction or transfer function consists of 15 pairs of input and output values, from white (0%) through to black (100%). The transfer function is a curve, which can be saved and applied to other photographic images, prior to printing the matt inkjet copy print. The creation of the transfer function assumes the use of a digital step tablet, which is available from our websites or can be constructed easily with any suitable drawing software.

**Step 1 Inkjet Calibration Print**

Open the digital step tablet and make an unadjusted inkjet print, selecting the software options to ignore color management. This print should be on matt paper and use a matt paper media setting to avoid over-inking. Ignore if it has a color hue or a tonality, different from what you may have expected. The print is allowed to dry and is hung on an evenly lit wall.

**Step 2 Calibration Copy Negative**

Set your film camera up opposite and perpendicular to the inkjet calibration print and make two exposures, one using an incident light reading at the effective film speed and another giving 1 stop overexposure (see fig.4). Develop the film with N+1 development. The resulting increase in negative contrast helps to avoid needing extreme contrast grades at the printing stage, and gives some freedom for further manipulation in the darkroom. In general, any film can be used, but it is of benefit to select the same film as for other direct silver prints in your collection. That way, a homogeneous exhibition of prints can be achieved. After calibration, store the negative, as it can be used for subsequent calibrations with other silver-gelatin paper.

**Step 3 Silver-Gelatin Calibration Print**

It may take several attempts to make a silver-gelatin print from the calibration copy negative at an exposure and contrast setting that just shows a full range of image tones from white to black. Note the contrast setting and metering method for later use. For films with an extended toe region, the overexposed negative may be more suitable. A typical silver-gelatin calibration print, as shown in fig.5, exhibits a high midtone contrast as well as blocked highlights and shadows.

**Step 4 The Transfer Function**

The transfer function must compensate for the tonal deviation that the inkjet copy print, the copy negative and the silver-gelatin print process introduce into the copy-print process. The relationship between the target densities of our personal rendering intent and the actual output densities of the silver-gelatin calibration print provides a direct measure of the compensation required, and it is the basis for the transfer function.

Take the calibration print and, using a densitometer, find the patches closest in value to the desired target densities. Interpolate the values if necessary, and list the actual percentages in the output column of a table similar to the one shown in fig.6. The values are then entered into the imaging software, appropriately labelled and saved for later application (fig.7). The transfer function will most likely resemble an inverse S-curve (fig.10), reducing midtone contrast and increasing highlight and shadow contrast.

**Final Optimization**

A close look at the curve of the silver-gelatin calibration print in fig.7 reveals a dramatic change in contrast between the tonal extremes and the midtones. As a result, the tonality of the silver print is sensitive to digital highlight values and print exposure. To identify potential problems and provide data required to tune the transfer function, it is useful to print a small step wedge on the margins of the matt inkjet copy print (shown in fig.1), which is used to verify the consistency of the inkjet printer and our darkroom work.

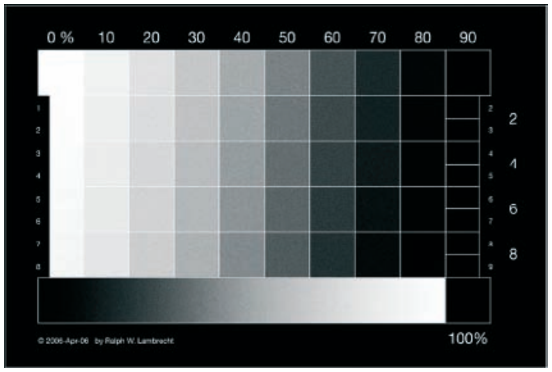


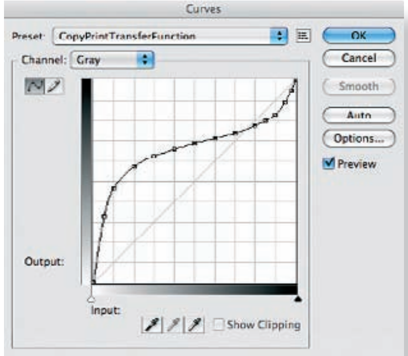
fig.5 This example of a silver-gelatin calibration print has noticeably compressed highlight and shadow tones, as well as high-contrast midtones. A little care is required with print exposure and contrast settings to ensure a full range of tones. In this case, an ISO(R) value of 75 proved sufficient, together with a negative developed to (N+1) contrast.

**Transfer Function Example**

(monitor $\gamma = 2.2$ > inkjet print > MGIV-FB)

| Input | target density | Output at |
|---|---|---|
| 0 % | 0.05 | 0 % |
| 5 % | 0.11 | 33 % |
| 10 % | 0.16 | 47 % |
| 20 % | 0.27 | 57 % |
| 30 % | 0.38 | 62 % |
| 40 % | 0.51 | 66 % |
| 50 % | 0.66 | 69 % |
| 60 % | 0.83 | 71 % |
| 70 % | 1.04 | 74 % |
| 80 % | 1.30 | 77 % |
| 85 % | 1.45 | 80 % |
| 90 % | 1.63 | 83 % |
| 95 % | 1.84 | 89 % |
| 98 % | 1.99 | 95 % |
| 100 % | 2.10 | 100 % |

fig.6 Using the calibration print and a densitometer, the patches closest in value to the desired target densities are determined. The actual percentages, achieving target density values, are listed in the output column. A template for this table can be found in the appendix.



Preset: CopyPrintTransferFunction
Channel: Gray

fig.7 This sample 'Curves' adjustment dialog box in Adobe Photoshop shows a transfer function, correcting for my particular printer, film and darkroom setup. Although your settings will most likely differ, the overall shape of the curve will be very similar, as it is determined by the general characteristics of inkjet, film and paper. This transfer function is applied to the digital image, just prior to printing the inkjet copy print onto matt paper. As you can see, with my setup, the highlight contrast must be increased by about 500%, the shadow contrast by about 200%, whereas the midtone contrast must be reduced by about 60%.

## Comparing with Other Processes

The copy-print process successfully combines digital and analog photography. What follows is a brief comparison with alternative digital negative techniques.

### Halftone Negatives

It is interesting to look back on our two distinct methods to create a silver-gelatin print from a digital file. In the case of the halftone negative (fig.9), we have a very repeatable and robust method. It resists later manipulation to some extent but requires available imagesetter facilities, which are getting increasingly harder to find these days. The process requires planning and careful execution to ensure the final silver-gelatin print has the required size and tonality. On the other hand, the copy-print process is more flexible, in that it produces a traditional negative on film and can be manipulated conventionally in the darkroom. This convenience comes at a price, because it requires greater rigor at the inkjet printing, copying and developing stages to ensure accurate tonality.

### Inkjet Negatives

Following in the footsteps of Dan Burkholder and others, I also evaluated the application of full-size inkjet negatives for contact printing (fig.10), to create a fine-art silver-gelatin print from a digital file. In common with other respected photographers, we were unable to consistently make convincing silver-gelatin prints from an inkjet negative. Unlike alternative print processes on coated matt paper, silver-gelatin paper has a very high resolution and shows the smallest negative detail or imperfection, which is lost when making inkjet prints. During our research, several clear and white plastic substrates were tried and ultimately rejected as a suitable material for inkjet negatives.

Contact prints from clear film show obvious evidence of its mechanistic origin, revealing regular inkjet dots and mild banding (fig.11a), even if the printer head is perfectly aligned and ink-nozzle are at peak performance. The same issues are present, but to a lesser extent, with translucent white plastic film (fig 10b). Although its diffusing properties disguised

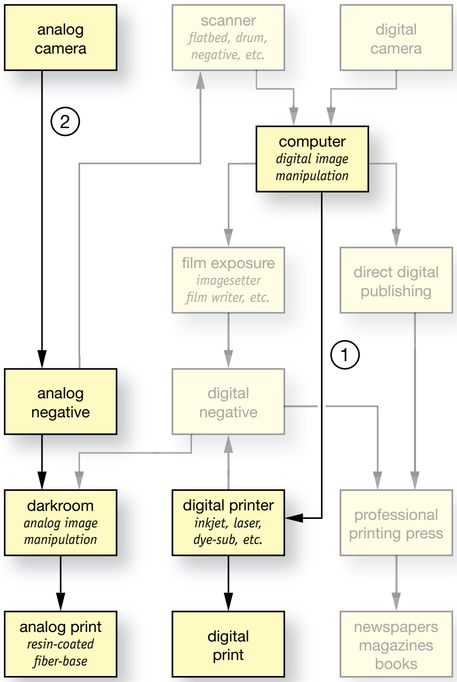

analog camera
scanner
flatbed, drum, negative, etc.
digital camera
②
computer
digital image manipulation
film exposure
imagesetter film writer, etc.
direct digital publishing
①
analog negative
digital negative
darkroom
analog image manipulation
digital printer
inkjet, laser, dye-sub, etc.
professional printing press
analog print
resin-coated fiber-base
digital print
newspapers magazines books

fig.8 the two copy-print process imaging paths

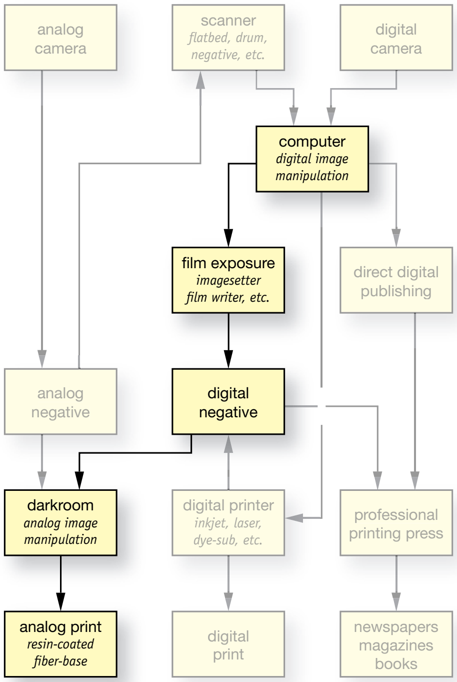

analog camera
scanner
flatbed, drum, negative, etc.
digital camera
computer
digital image manipulation
film exposure
imagesetter film writer, etc.
direct digital publishing
analog negative
digital negative
darkroom
analog image manipulation
digital printer
inkjet, laser, dye-sub, etc.
professional printing press
analog print
resin-coated fiber-base
digital print
newspapers magazines books

fig.9 the halftone-negative imaging path

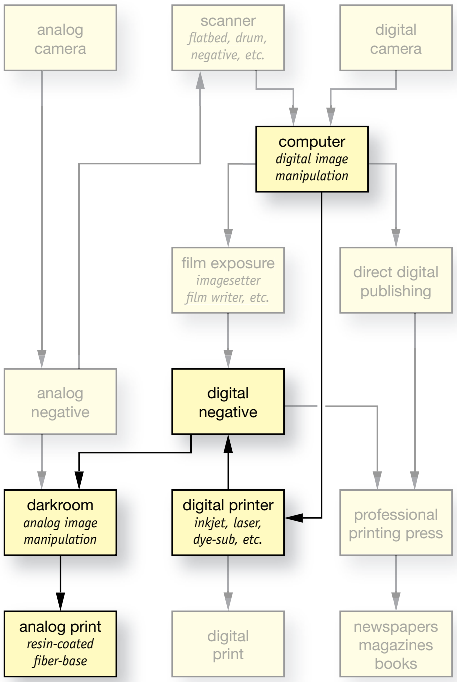

analog camera
scanner
flatbed, drum, negative, etc.
digital camera
computer
digital image manipulation
film exposure
imagesetter film writer, etc.
direct digital publishing
analog negative
digital negative
darkroom
analog image manipulation
digital printer
inkjet, laser, dye-sub, etc.
professional printing press
analog print
resin-coated fiber-base
digital print
newspapers magazines books

fig.10 the inkjet-negative imaging path

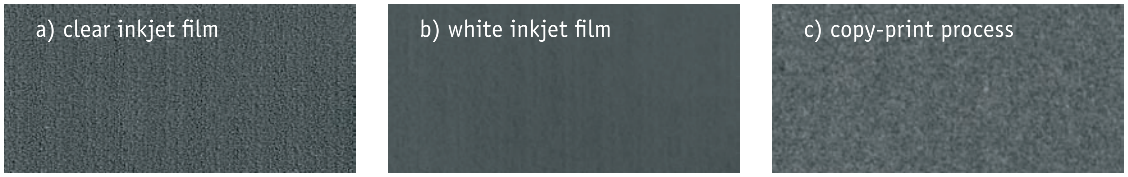
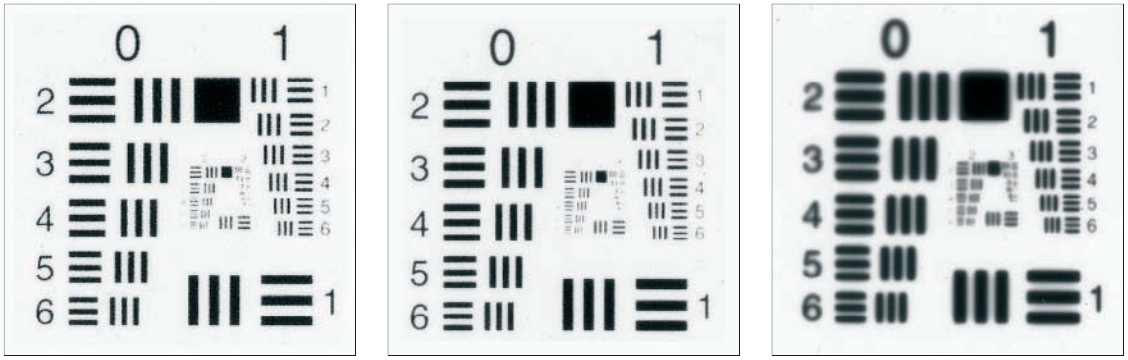


fig.11 In the magnified scan of a contact print, which was made by using a clear inkjet film (a), vertical banding and individual inkjet dots are clearly visible, especially in the midtones. The vertical banding was greatly reduced, but not completely removed, by using white inkjet film and applying some pressure through the weight of a thick glass cover (b). Another scan of a silver-gelatin print, made by using the copy-print process (c), proves that this technique successfully masks printer issues such as ink dots or banding. The combination of a matt paper surface, ink dot gain and negative grain disguises all hardware issues.



a) clear inkjet film, clamped

b) white inkjet film, clamped

c) white inkjet film, weighed down

fig.12 These magnified scans of contact-printed, silver-gelatin prints demonstrate the typical resolution performance of inkjet-negatives, resolving up to 8.0 lp/mm in a) and b), if lightly clamped between the paper and normal picture glass. Relying on the weight of the glass alone, as in c), caused negative and paper to be close but not touching in all areas, resulting in a blurry image and lost resolution. Even with clamped glass, it is not uncommon to have uneven sharpness.

| attribute | clear film | white film | copy-print process |
|---|---|---|---|
| resolution | ★★★★ | ★★ | ★★★ |
| gradation | ★ | ★★ | ★★★ |
| granularity | ★ | ★★ | ★★ |
| flexibility | ★ | ★ | ★★★ |
| repeatability | ★★ | ★ | ★★★ |
| permanence | ★ | ★ | ★★★★ |

fig.13 This table summarizes and compares the performance of two inkjet-negative methods with the copy-print process, showing superior gradation, repeatability, flexibility and permanence by making regular film negatives from adjusted inkjet prints.

the inkjet dot patterns if properly clamped, in practice, the smallest gap between the facedown negative and printing paper degrades the print resolution to less than acceptable levels (fig.12). Also, white inkjet films work best with large-format dye-based printers, which limit the maximum transmission density and require a high-contrast setting, further accentuating the inkjet-negative limitations.

It is also difficult to make prints from inkjet negatives with smooth tonality in highlight regions. Digital imaging systems are optimized for positive images and have about 5x more tonal resolution in highlight than in shadow areas, to match our eye's ability to discriminate print tones. When one considers an inkjet negative, one needs the opposite by requiring fine tonal discrimination in high-density areas.

With each trial, the copy-print process produced a silver print with superior gradation to that of an inkjet negative print, especially in the highlight regions, and all signs of the mechanistic properties of the inkjet printer vanished, masked by the inclusion of film grain and the print qualities of the matt inkjet paper. Fig.11c demonstrates this with an enlarged scan of a silver print from a Kodak Tri-X negative. Unlike the images in fig.11a-b, this print exhibits normal film grain and no signs of its mechanistic origins.

## Final Thoughts

The copy-print process is the most tolerant and practical method to make fine silver prints from digital files with a variety of inkjet printers, inks and media (fig.13). The extra steps involved introduce a mild resolution loss, but it is insufficient to impact the perceived resolution of a print at the normal viewing distance. Additional sharpening of the original digital image can compensate the mild softening. In cases where a portfolio is made from a mixture of classical and digital images, the lack of telltale inkjet dots and the presence of film grain disguise the reproduction process to create a homogeneous body of work with other conventional silver prints.

Although this copy process requires additional materials, matt inkjet papers cost significantly less than plastic film, and the resulting conventional negative allows final images to be printed at any size and classically manipulated under the enlarger. A hidden benefit is the realization that A4 inkjet printers have sufficient resolution for critical silver-gelatin print resolution after they have been copied. Furthermore, these negatives can be archivally processed, stored conveniently in standard negative filing systems, and the matt copy prints discarded. By using the same film stock, the appearance of the final print can be made so it is virtually indistinguishable from a conventional print. Although digital halftone negatives can produce high-quality prints, their lack of grain is a clue to their origin, unless, that is, you are really ingenious and add it artificially to the digital image file.

## Review Questions

1. Which of the following is true about exposure?
    a. panchromatic film is evenly sensitive to all colors of light
    b. matrix metering is equivalent to spot metering in the Zone System
    c. very long exposure times do not follow the reciprocity law
    d. underexposure can be compensated with overdevelopment

2. What is the best way to photograph a high-contrast scene?
    a. take an incident reading to average the contrast range
    b. expose normally and decrease development
    c. increase exposure and decrease development
    d. set the meter to a higher exposure index

3. Which of the following is true about film exposure latitude?
    a. film has very little overexposure latitude
    b. film has several stops of overexposure latitude
    c. latitude does not change with exposure
    d. latitude does not change with development

4. What is the purpose of pre-exposing film?
    a. adding shadow detail to the negative
    b. increasing overall negative contrast
    c. increasing highlight separation
    d. avoiding reciprocity failures

5. How can I tell that a negative was underexposed and overdeveloped?
    a. the rebate numbers are very faint
    b. impossible to tell before making contact sheets
    c. it will print better on a harder paper
    d. shadows are too weak and highlights are too dense

6. Which of the following is true about unsharp masking?
    a. it can rescue an underexposed negative
    b. it increases apparent print sharpness
    c. it cannot be used to rescue excessively high-contrast negatives
    d. it only works with large-format negatives and special equipment

7. What is the benefit of hybrid printing?
    a. it combines the advantages of analog and digital technologies
    b. it does not require a darkroom
    c. it is the fastest way to make a print
    d. it is a low-cost alternative, but it affects print longevity

1c, 2c, 3b, 4a, 5d, 6b, 7a

© 2000 by Chris Woodhouse, all rights reserved

# Advanced Print Control

This page intentionally left blank

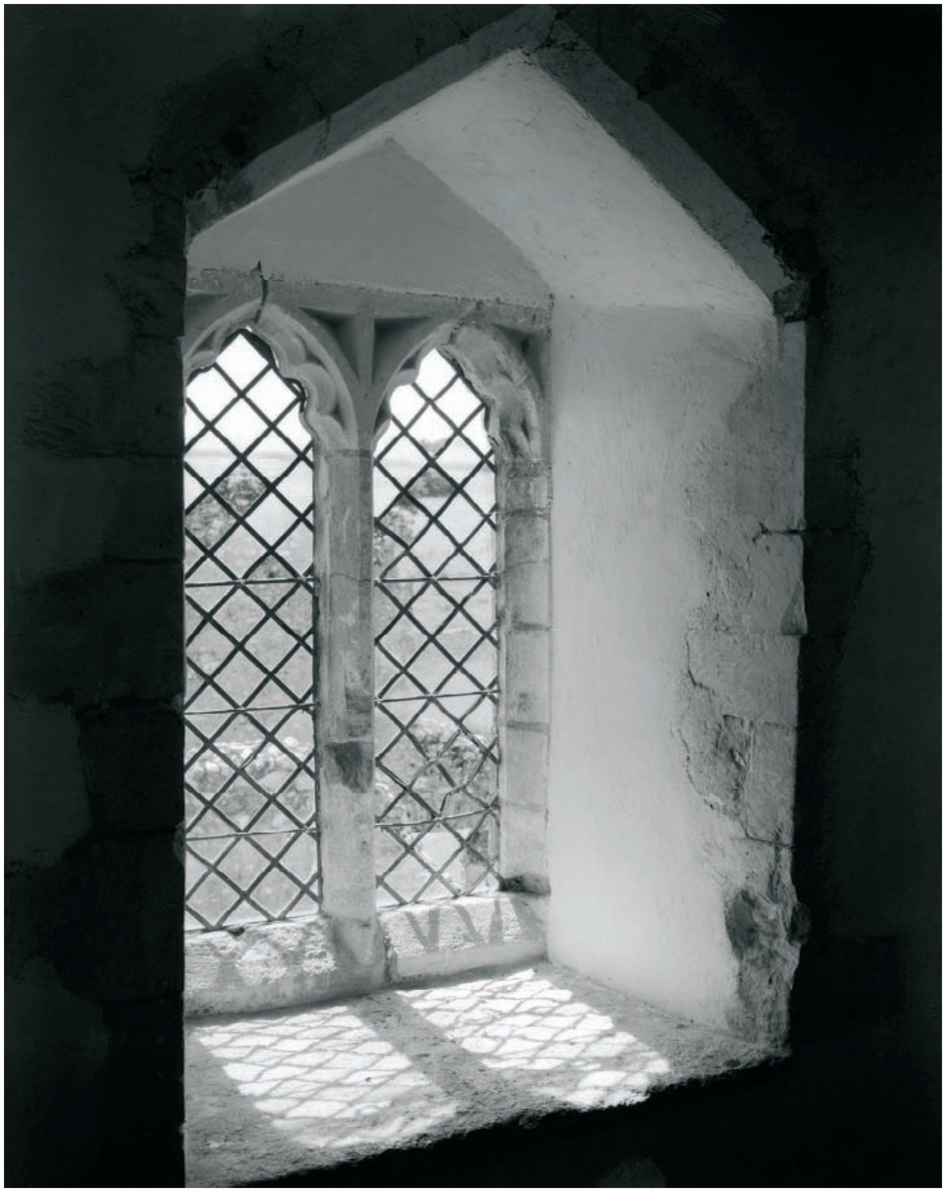
# Fine-Tuning Print Exposure and Contrast

## Optimizing the print for the discriminating human eye

The old axiom for creating high-quality negatives is 'expose for the shadows and develop for the highlights'. When it comes to printing negatives in the darkroom, this recommendation appropriately changes to 'expose for the highlights and control the shadows with contrast'. That is good advice, but as experienced printers know, there often is a small difference between a good and a mediocre print. So, when it comes to fine-tuning exposure and contrast, how concerned do we really need to be about the optimal settings? How much deviation is acceptable, and how little is recognizable? What are the smallest increments we need to work with? How do we advance from casual work to fine-tuned images without going completely overboard? Exploring a sample print of the Castle Acre Priory will provide some answers.

Castle Acre Priory is located just five miles north of Swaffham in Norfolk, England. Its ruins span seven centuries and include an elaborately decorated 12th-century church, a 15th-century gate house and the prior's former living quarters, which are still fit to live in.

The picture on this page was taken inside of the prior's chapel in July of 1999. I used my Toyo 45AX with a Nikkor-W 135 mm, f/5.6 on a tripod. This metal field camera travels well, and is fast and easy to set up, considering the large 4x5-inch format. The 135mm lens was required, because the room is very small, and I was not able to step back any farther. I measured the scene with my Pentax Digital Spotmeter and placed the dark interior wall on Zone III, in order to keep the option of some detail. The bright vertical wall of the window fell on Zone VII, but due to the bright sunlight, the windowsill was clearly on Zone XI. To pull the sill back onto Zone VIII, N-3 development was needed. I changed the EI to 25, as is necessary when dealing with a rather broad subject brightness range such as this, in order to sufficiently expose



© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50037-5

fig.1 The display illumination levels of a photograph significantly influence how much detail the human eye perceives in the highlight and shadow areas of the print.

| | Zone | | | | illumination | | display lighting |
|---|---|---|---|---|---|---|---|
| | VIII | VII | III | II | | | |
| reflection density | 0.08 - 0.12 | 0.15 - 0.25 | 1.48 - 1.72 | 1.81 - 1.95 | | | |
| EV (ISO 100/21°) | human eye discriminates a 1/24-stop exposure difference at grade 2.5 | | | | lux | ft-cd | |
| 1 | No | faint | No | No | 5.4 | 0.51 | too dark |
| 3 | faint | Yes | No | No | 22 | 2.0 | |
| 5 | faint | Yes | faint | No | 87 | 8.1 | |
| 7 | faint | Yes | Yes | faint | 350 | 32 | minimum |
| 8 | faint | Yes | Yes | faint | 700 | 65 | practical |
| 9 | faint | Yes | Yes | faint | 1,400 | 130 | medium |
| 10 | faint | Yes | Yes | faint | 2,800 | 260 | critical |
| 11 | faint | Yes | Yes | faint | 5,600 | 520 | maximum |
| 13 | No | faint | Yes | Yes | 22,000 | 2,100 | too bright |
| 15 | No | faint | Yes | Yes | 89,000 | 8,300 | |

**Standard Print Illumination**

ISO 3664:2009

| | |
|---|---|
| practical appraisal | 500 lux ±25 |
| critical evaluation | 2,000 lux ±250 |

Kodak's TMax-100. This will maintain shadow detail when the development time is shortened. At f/32, the calculated exposure time was 8 seconds, but I extended it to 12 seconds to compensate for this film's reciprocity behavior.

When printing the image in the darkroom, it became obvious that the N-3 development had pushed the subject Zone III closer to a print Zone II. Actually, the image looks better this way, but I was glad that I had given enough exposure time to get at least good tonality from the shadows, even though most of the detail was lost. With this treatment, the image printed well on grade-2 paper and only required minor burning down of the upper corners. I consider this print to have a full tonal scale from Zone II to VIII, which makes it a prime candidate to discuss optimized print exposure and contrast.

## Print Exposure

It makes little sense to print highlights lighter or shadows darker than what the human eye is able to discern under normal lighting conditions. Neither does it make sense to worry about exposure differences that are too small to see. With that in mind, some questions need to be answered.

### 1. What are 'normal' lighting conditions?

The first to answer this question was Henry Dryfuss through extensive research conducted in the 1960s, which is fully documented in his book *The Measure of Man*. He established lighting conditions for coarse, medium and fine manual work. His recommended illumination levels were initially meant for manual labor conducted over several hours, but they are also adequate to view photographic prints. Subsequent viewing standards, ANSI PH2.30-1989 and the current version ISO 3664:2009, are based on his work.

Fig.1 shows Henry Dryfuss's findings, and I included the conversion to EVs at ISO 100/21° so that you can quantify illumination levels with your own lightmeter. Consequently, EV 7 is the minimum illumination at which a print should be displayed, and there appears to be no benefit to illuminate beyond EV 11. This range seems to be reasonable, based on the display lighting conditions in my own home and those found in galleries. When lighting levels drop below EV 7, previously well-detailed shadows get too dark for good separation. At illuminations above EV 11, previously well-detailed highlights tend to bleach out. This is the logic behind the recommendation to print with the display conditions in mind, as advocated in Ansel Adams' book *The Print*. A picture to be hung in the dark hallway of the local church must be printed lighter than the same picture exhibited in a well-lit photographic gallery. I recommend printing for 'normal' lighting conditions of EV 8 to EV 10, if the final display conditions are not known.

fig.2 The ISO standard concentrates on the textural density range of the paper characteristic curve, ignoring most of the flat, low-contrast areas of toe and shoulder, because they have little practical value for pictorial photography.

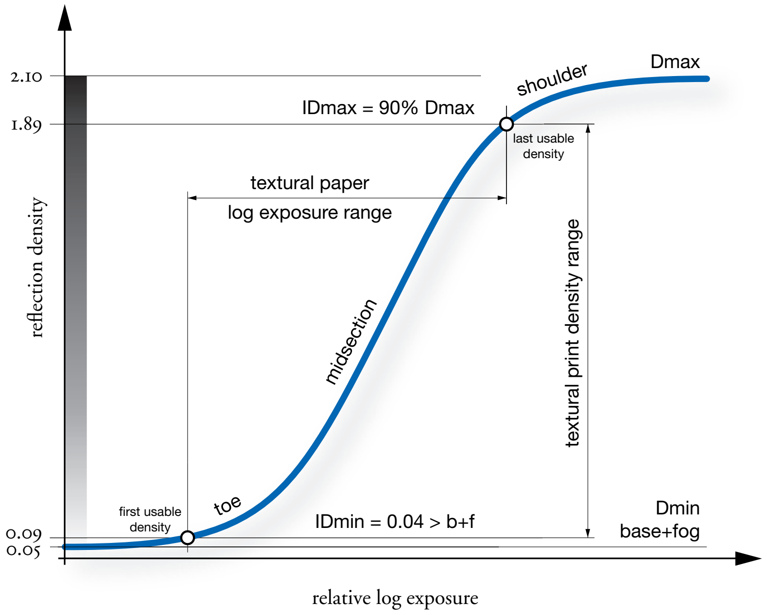


Fig.1 also reveals that the shadows are more affected by dim light than the highlights are affected by bright light. It would, therefore, be safer to examine the image at the lower threshold of display illumination while printing. I study my prints in the darkroom on a plastic board next to my sink. It is illuminated to read EV 6 with a lightmeter set to ISO 100/21°. This ensures good shadow detail in the final print. If I can see details in the shadows at EV 6, I will be able to see them under normal lighting conditions too. But, if the evaluation light is too bright, there is a danger that the prints will be too dark under normal lighting conditions. As an additional benefit, printing shadow detail for EV 6 also helps to compensate for the dry-down effect.

### 2. What are the reflection density limits for tonality?

The Zone System defines the tonality limits as Zone VIII for the highlights and Zone II for the shadows. There is no universal agreement on precise reflection densities for the equivalent print zones, but the existing standard for paper characteristic curves, ISO 6846, can help to define approximate values. Fig.2 shows how this standard concentrates on the textural density range of the characteristic curve, by ignoring the low-contrast areas of both the toe and the shoulder, because they have little practical value for pictorial photography.

The standard defines the 'first usable density' as being 0.04 above the base density of the paper. Most fine-art printing papers, including Ilford's Multigrade IV, have a base white of about 0.05 reflection density. Therefore, we will place Zone VIII at about 0.09 reflection density for most papers. Some warm tone papers, or papers with an ivory base, may have a slightly higher value due to the fact that they have a less reflective base white, but they are in the minority.

The current ISO standard defines the 'last usable density' as being 90% of the maximum density, also called Dmax. Another factor to be considered is the sensitivity limit of the human eye to shadow detail. I conducted a field test in 'normal' lighting conditions at around EV 8. Six people were asked to identify the darkest area with still visible detail on 30 different prints. The mean of 180 density readings was 1.88 with a standard deviation of 0.09 density. Today's glossy or pearl papers have Dmax densities of about 2.10, or higher if toned. The 90% rule of the ISO standard points to a 'last usable density' of 1.89 on these papers.

The almost precise correlation of the two numbers is a coincidence. However, the agreement of these two methods, as well as good corroboration with studies by other authors, including *Controls in B&W Photography* by Richard Henry, seems to indicate that this value is a good approximation for the 'last usable density'. Consequently, we will place Zone II at about 1.89 reflection density for most papers. There is a minority of matte surface papers, or papers with textile surfaces, which have significantly lower Dmax values, and for these papers the use of the 90% rule is more appropriate to calculate the 'last usable density'.

### 3. How discriminating is the eye to reflection density differences?

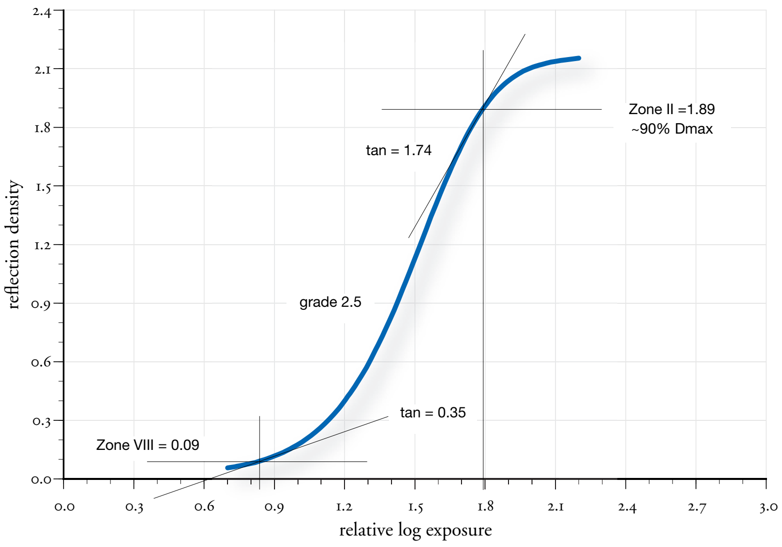
The answer to this question will determine how concerned we need to be about print exposure differences. A 'rule of thumb', adopted by some printers, has been that a 20% change in exposure is significant, a 10% change is modest, and a 5% change is minute. In conventional f/stop timing terms these values closely correlate to 1/3, 1/6 and 1/12 stop, respectively. I conducted another experiment to find the answer.

Two step tablets were exposed and processed. For each, I used a piece of 5x7-inch paper and printed seven, 1-inch wide bars onto it. One step tablet was printed around the Zone VIII target density of 0.09 and the other was printed around a density of 1.89 to represent Zone II. The bars differed in exposure

| Zone | print reflection density | detectable reflection density difference | exposure difference grade 2.5 [f/stop] |
|---|---|---|---|
| VIII | 0.08 - 0.12 | 0.003 | 1/24 |
| VII | 0.15 - 0.25 | 0.004 | 1/48 |
| V | 0.62 - 0.89 | 0.008 | 1/96 |
| III | 1.48 - 1.72 | 0.012 | 1/48 |
| II | 1.81 - 1.95 | 0.016 | 1/24 |

fig.3 The human eye is most sensitive to reflection density differences in the highlights. However, the eye shows about the same sensitivity to exposure differences in highlight and shadows, while exposure deviations are most obvious in the midtones.

fig.4 The eye's lack of sensitivity to the density differences around Zone II is entirely compensated by the increased contrast capability of the material at Zone II.



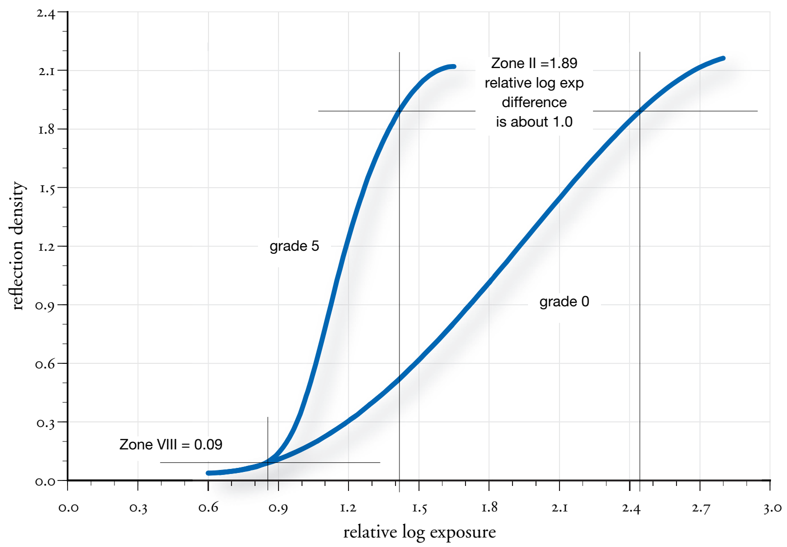


fig.5 Zone VIII highlights of grade 0 and 5 are placed on top of each other to determine the relative log exposure difference of the shadows in Zone II.

| ISO grade | exp range limits | avg exp range |
|---|---|---|
| 0 | 1.40 - 1.70 | **1.55** |
| 1 | 1.15 - 1.40 | 1.28 |
| 2 | 0.95 - 1.15 | 1.05 |
| 3 | 0.80 - 0.95 | 0.88 |
| 4 | 0.65 - 0.80 | 0.73 |
| 5 | 0.50 - 0.65 | **0.58** |

fig.6 All standard paper grades have a defined log exposure range to match different negative density ranges.

by 3%, or 1/24 stop. The results were presented to a different group of six people. The individuals were all able to see faint differences between the bars in lighting conditions from EV 7 to EV 11, and it seemed to be equally difficult to differentiate highlights and shadows. The test was repeated by cutting the exposure difference to 1.5% or a 1/48 stop. In this test, four individuals had difficulty detecting any bars. I concluded that 1/24 stop was about the limit of detecting exposure differences in Zone II and VIII under normal lighting conditions using adjacent gray bars. The results of the related density measurements are shown in fig.3. The densitometer revealed that a 1/24-stop exposure difference was responsible for a density difference of only 0.003 at Zone VIII, but 0.016 at Zone II. Therefore, we can conclude that the human eye is about 5 times more sensitive to density differences in the highlights as opposed to the shadows. However, as far as exposure difference is concerned, the discrimination of the eye is about the same between highlights and shadows. Fig.4 can help to explain this fortunate condition.

The contrast at any point on the characteristic curve can be quantified by creating a tangent to the curve at said point. The tangent of the resulting angle is a proportional measure of contrast. As you can see in fig.4, the tangent at the Zone II density is about 5 times greater than the tangent at the Zone VIII density. Therefore, the eye's lack of sensitivity to the density differences around Zone II is entirely compensated by the increased contrast capability of the material at Zone II. This explains why we need a similar exposure to get the same discrimination between highlights and shadows.

When I repeated the whole test with approximate density values for Zone III through Zone VII, I found that 1/48-stop exposure difference was still detectable at Zone III and Zone VII and not at all difficult to see at Zone V. The increased local contrast in these areas explains these findings, but our printing efforts will concentrate on Zones VIII and II to optimize highlight and shadow detail. Nevertheless, the additional data was valuable to complete fig.1 and 3, and it might also be useful for images that don't include the entire tonal scale.

It must be added at this point that the entire test was done with adjacent gray bars. My experience shows that our eyes are more discriminating to this condition than comparing two photographs, even if they are identical images and right next to each other. Our ability to compare two identical images in isolation is even further reduced. Therefore, I find an exposure tolerance of 1/24 stop to be rather demanding. I have adopted a tolerance of 1/12 stop for my own work, which is more practical and sufficient for most prints. However, 1/24 stop can be useful with images printed on harder papers, because they have much higher contrast gradients.

In conclusion to our concern of fine-tuning print exposure, we may take a final look at fig.1 and answer all three questions simultaneously. Normal lighting conditions for display prints should be from EV 7 to EV 11. The approximate log reflection densities for Zone VIII and II are 0.09 and 1.89, respectively, on most papers. The minimum exposure difference to alter the tonal values of a print appreciably is about 1/12 stop, but can be 1/24 stop with harder papers. This is a verification of the 'rule of thumb' mentioned earlier. Shadow detail suffers first and rapidly, when illumination drops below EV 7, and it is valuable to examine print progress at EV 6 to secure this detail. Highlight detail is not as sensitive to different illumination levels as shadow detail, but it is important to have precise highlight exposure, because the eyes are most sensitive to density variations in the highlights.

## Print Contrast

The desired shadow detail is typically fine-tuned with paper contrast after the highlight exposure has been set. The recommended rule of thumb is to start with a soft paper-grade estimate and then slowly move up in contrast until the desired shadow detail has been reached. The trial and error portion of this approach can be minimized, if we realize that contrast can also be referred to as the exposure of the shadows.

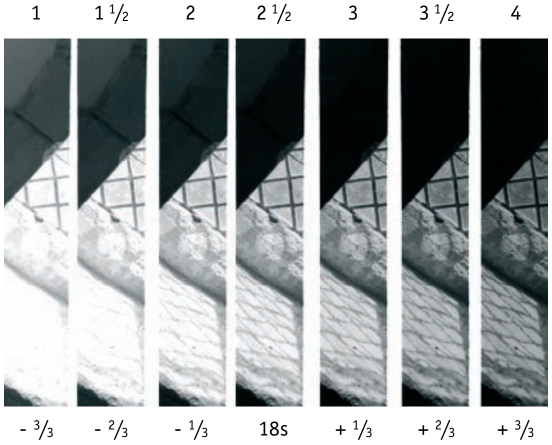
We can use fig.5 to determine the required exposure for Zone II. Only the characteristic curves for the paper contrast limits, grade 0 and 5, are shown. I made sure that both papers were exposed so that the highlights of Zone VIII were rendered with the same reflection density. This allows us to measure the relative log exposure difference between the shadows of these two paper grades. In other words, the highlights were placed on top of each other to see how much the shadow exposures differ from each other. The shadows differ by about 1.0 log exposure.

A different method is shown in fig.6, and it leads to the same conclusion. All standard paper grades have a defined log exposure range to match different negative density ranges. Soft papers have a low grade number and a wider exposure range than hard papers, which have a high grade number. Although all grades have exposure ranges expressed within the shown limits to accommodate manufacturing tolerances, we need only to concern ourselves with the average exposure ranges for this exercise. The difference between the average exposure ranges of grade 0 and 5 is, reading from the table, 1.55 - 0.58 = 0.97 log exposure. This is a very similar value to the log exposure difference 1.0, which we already got from fig.5 earlier.

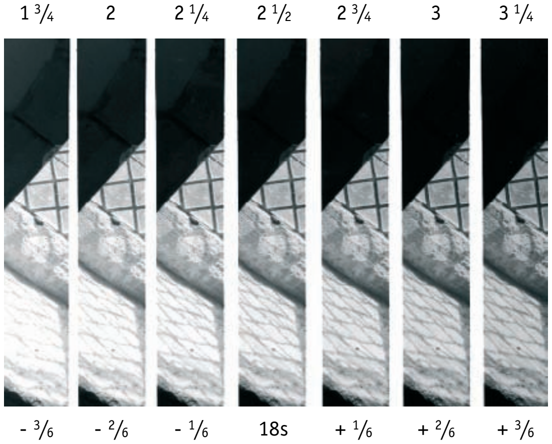
Paper grades are often subdivided in 1/2-grade increments to provide enough flexibility to fine-tune image contrast. This provides ten increments between grade 0 and 5, and we can assume, within a reasonably small error, that the log exposure difference between grade 0 and 5 is linear. Consequently, a log exposure difference of about 1.0, between grade 0 and 5, divided by ten increments results into a 0.1 log exposure difference between 1/2-grade increments. By definition, a log exposure of 0.3 equals one stop of exposure difference, and therefore, in average, a 0.1 log exposure difference makes for a 1/3-stop exposure difference between 1/2-grade increments.

| f/stop exposure | ISO grade |
|---|---|
| 1 1/3 | 2 |
| 1 | 1 1/2 |
| 2/3 | 1 |
| 1/3 | 1/2 |
| 1/6 | 1/4 |
| 1/12 | 1/8 |

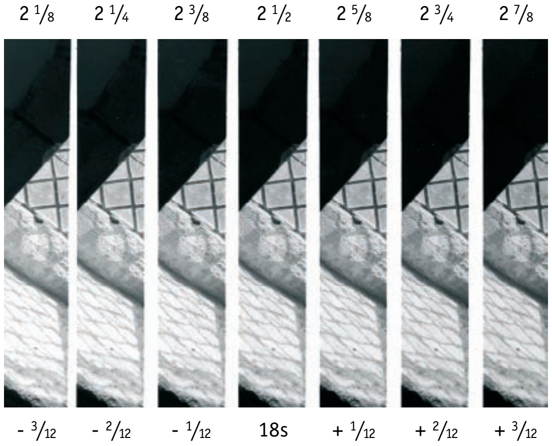
fig.7 There is a relationship between the f/stop exposure differences of the shadows and paper-grade deviations, if the highlight exposure is kept constant.



a) coarse increments (significant change)



b) medium increments (modest change)



c) fine increments (minute change)

fig.8a-c Test strips with the same base exposure, but different exposure increments, can be used to determine desired shadow detail and contrast. All test strips have a target exposure of 18 seconds, with f/stop increments of 1/3, 1/6 and 1/12 stop, decreasing to the left and increasing to the right. The paper contrast was kept constant at grade 2.5, but the different exposures reveal different shadow detail, predicting a target contrast grade (labeled on top) without any additional testing.

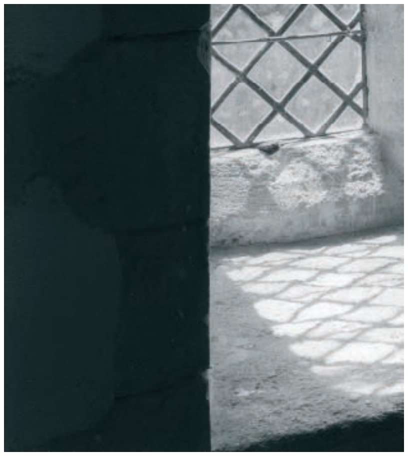


fig.9a grade 2 at 17.0s

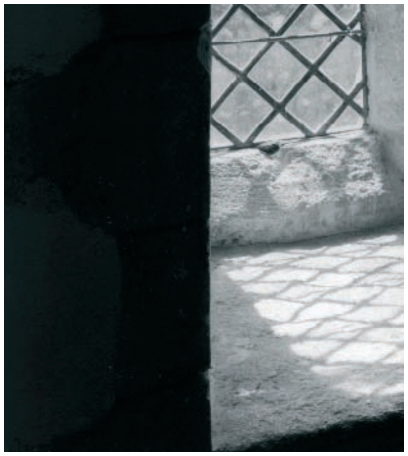


fig.9c grade 2 1/2 at 18.0s

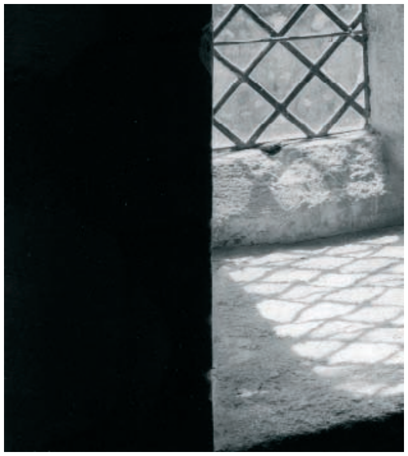


fig.9e grade 3 at 19.0s

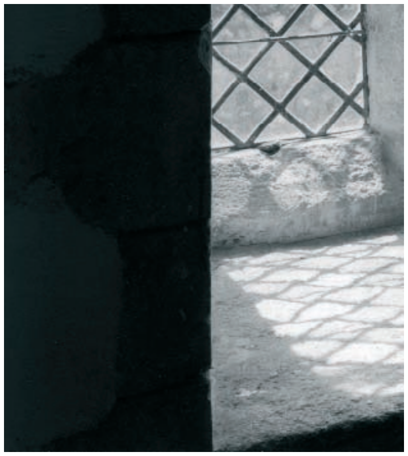


fig.9b grade 2 1/4 at 17.5s

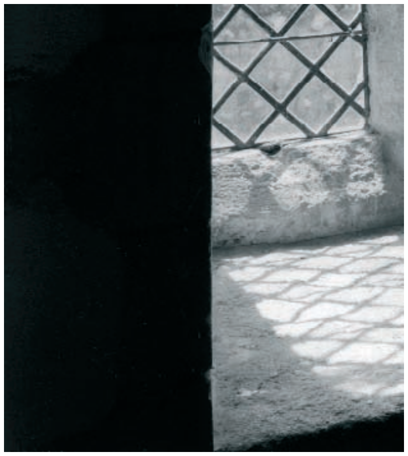


fig.9d grade 2 3/4 at 18.5s

fig.9a-e The highlight detail in the lower left corner of the lead picture was printed to a consistent highlight density, but the paper contrast was incremented by 1/4 grade. Compare the final shadow contrast here with the contrast predictions in fig.8b.

Fig.7 shows the relationship between the f/stop exposure differences of the shadows and paper-grade deviations, if the highlight exposure is kept constant. This discovery has placed the value of test strips into a completely different light for me. In the past, I looked at test strips purely as a tool to determine accurate highlight exposure. Moreover, I resisted looking at the shadow detail in test strips, because I knew how confusing it can be to determine exposure and contrast at the same time. Only after the highlight exposure was set did I modify the shadow detail by slowly changing paper contrast. I still believe that there is much value in this approach, and I would not recommend anything else to a beginning or practicing printer. However, I'm glad that Paul Butzi pointed out to me that an advanced darkroom practitioner can get valuable information about the desired paper contrast by evaluating the shadow detail of the test strip.

Fig.8 shows three test strips, which differ only by the exposure increments used. They have all been printed at grade 2 1/2 and have the same base exposure of 18 seconds in the center. The exposure decreases to the left and increases to the right. Figures 8a-c, from top to bottom, were prepared in 1/3, 1/6 and 1/12-stop exposure increments, respectively. There is enough information here to fine-tune the highlight exposure securely down to 1/12 stop. Let's assume, for this example, an exposure of 18 seconds to be just right.

Now, we can take a look at the shadow detail on the different test strips. Unfortunately, I cannot predict how easy it will be to see a difference in the final reproduction of these test strips. However, in the originals, there are clear differences in the upper left corner shadows of fig.8a, a modest difference in fig.8b and a minute, but still visible, difference in fig.8c. From fig.7, we know that 1/3, 1/6 and 1/12-stop exposure differences are equivalent to 1/2, 1/4 and 1/8 grade, respectively.

Therefore, we can look at highlight and shadow detail on different test strips and select one each to our liking. We will then know immediately what exposure time is required to retain highlight detail, and what contrast change is required to achieve that level of shadow detail. As an example, if we like the highlight detail of the center strip in fig.8a, but we prefer to have the shadow detail of the second strip to the left, then the base exposure would remain at 18 seconds, but the contrast would have to be reduced by

1 grade. Fig.8b allows contrast selection down to 1/4 grade, because the exposure increments are only 1/6 stop. Fig.8c allows us to select contrast increments as low as 1/8 of a grade.

It should be added here that, depending on equipment and materials used, minute exposure changes might be required to maintain constant highlight exposure when changing paper contrast. I don't trust any claims of constant highlight exposure and have tested and calibrated all my tools to compensate for the effect. A detailed working method is found in 'Exposure Compensation for Contrast Change'.

### 4. How accurately do we need to select paper contrast?

Filter manufacturers seem to have answered this question for us. All filter sets on the market come in 1/2-grade increments, even though VC and dichroic color heads allow for much finer increments. In the previous section on print exposure, we concluded that an exposure increment of 1/12 stop is about as fine as we need to go. Theoretically, this statement is true for the highlight and the shadow detail, as proved in fig.3 and 4 and verified in fig.7 and 8c. There seems to be a difference, however, between what a viewer of a photograph is able to discriminate and what he or she is willing to discriminate. The eyes are first and foremost attracted to the lighter areas of an image. The shadow areas will eventually get the viewer's attention, but very dark or empty shadows are not interesting to most viewers. Nevertheless, an appreciation for contrast changes down to 1/8 of a grade exists, even though they are admittedly hard to see. I consider a 1/4-grade increment to be adequate, but find the standard 1/2-grade increment too rough for fine work.

Fig.9a-e show a sequence of an area from the lower left corner of the lead picture. The exposure was adjusted to have a consistent highlight reflection density, but the paper contrast was increased from a grade 2 in fig.9a to a grade 3 in fig.9e in 1/4-grade increments. Again, the final reproduction capability of the shadow detail is not known to me, but on the originals, one can clearly see the differences without any need for finer increments. Furthermore, we can see in fig.8b how the desired paper contrast was easily predictable from a simple exposure test. A test strip provides information about both exposure and contrast.

Fine-tuning print exposure and contrast is essential to obtain optimal print tonality. Granted, finding the most suitable highlight exposure within 1/12 stop and optimizing shadows within 1/4 grade takes some effort, because fine-tuning is most sensibly done through the evaluation of traditional test strips. The one-off approach of electronic metering is not suitable for a comparison of boundary conditions. Nevertheless, for the experienced printer, reading exposure and contrast off the same test strip is a welcome shortcut, which leads to sophisticated results without compromise.

# Measuring Paper Contrast

## Contrast calibration to standard paper grades

After an appropriate print exposure time for the significant highlights is found, shadow detail is fine-tuned with print contrast. Without a doubt, the universally agreed units to measure relatively short durations, such as exposure time, are seconds and minutes. However, when it comes to measuring paper contrast, a variety of systems are commonly used. Many photographers communicate paper contrast in form of 'paper grades', others use 'filter numbers', which are often confused with paper grades, and some photographers, less concerned with numerical systems and more interested in the final result, just dial-in more soft or hard light when using their color- or variable-contrast enlarger heads. Nevertheless, a standard unit of paper-contrast measurement has the benefit of being able to compare different equipment, materials or techniques while rendering printing records less sensitive to any changes in the future.

The actual paper contrast depends on a variety of variables, some more and some less significant, but it can be precisely evaluated with the aid of a reflection densitometer or at least adequately quantified with inexpensive step tablets. In any case, it is beneficial to apply the ANSI/ISO standards for monochrome papers to measure the actual paper contrast.

### Contrast Standards

Fig.1 shows a standard characteristic curve for photographic paper, including some of the terminology, as defined in the current standard, ANSI PH2.2 as well as ISO 6846. Absolute print reflection density is plotted against relative log exposure. The paper has a base reflection density and processing may add a certain fog level, which together add up to a minimum density called Dmin. The curve is considered to have three basic regions. Relatively small exposure to light creates slowly increasing densities

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50038-7

and is represented in the flat toe section of the curve. Increasing exposure levels create rapidly increasing densities and are represented in the steep midsection of the curve. Further exposure to light only adds marginal density to the paper in the shoulder section, where it finally reaches the maximum possible density called Dmax. The extreme flat ends of the curve are of little value to the practical photographer. In these areas, relatively high exposure changes have to be made in order to create even small density variations. This results in severe compression of highlight and shadow densities. Therefore, the designers of the standard made an effort to define more practical minimum and maximum densities, which are called IDmin and IDmax. IDmin is defined as a density of 0.04 above base+fog, and IDmax is defined as 90% of Dmax, which is the maximum density possible for a particular paper/processing combination.

Please note that according to the ISO standard IDmax is a relative measure. At the time the standard was developed, the maximum possible density for any particular paper/processing combination was around 2.1, which limited IDmax to a value of 1.89. This is a reasonable density limitation, in order for the human eye to comfortably detect shadow detail under normal print illumination. Modern papers, on the other hand, can easily reach Dmax values of 2.4 or more after toning, in which case, a relatively determined IDmax would allow shadows to become too dark for human detection. Therefrom, a fixed IDmax value of 1.89 is a more practical approach for modern papers than a relative value based on Dmax.

While limiting ourselves to the textural log exposure range between IDmin and IDmax, we can secure quality highlight and shadow separation within the paper's density range. With the exception of very soft grades, the textural density range is constant for each paper and developer combination. However, the textural log exposure range will be wider with soft paper grades and narrower with hard paper grades. It can therefore be used as a direct quantifier for a standard paper-grading system.

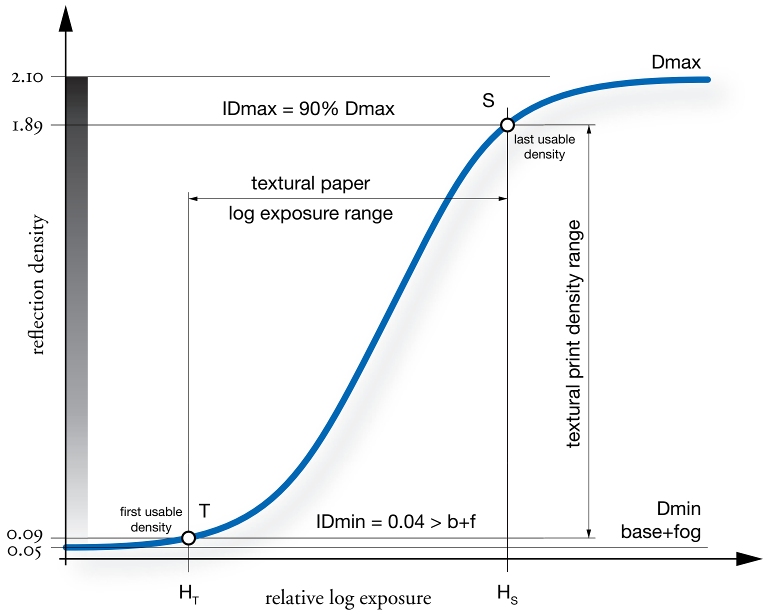
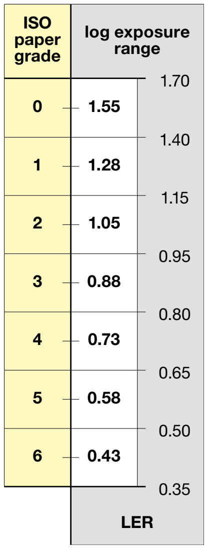


fig.1 The paper characteristic curve shows how the paper density increases with exposure. The textural log exposure range and the textural density range, between points 'T' and 'S', ignore most of the flat toe and shoulder portions of the curve to avoid compressed highlights and shadows.

Prior to 1966, photographic papers were missing a standard nomenclature for paper grades, because each manufacturer had a different system. The first standard concerned with paper grades was listed as an appendix to ANSI PH2.2 from 1966 (fig.2a). It divided the log exposure range from 0.50 to 1.70 into six grades, which were given numbers from 0 through 5 and labels from 'very soft' to 'extra hard'. Agfa, Ilford and Kodak had used very similar systems up to that time. A never-released draft of the standard from 1978 added the log exposure range from 0.35 to 0.50 as grade 6 without a label. In 1981, the standard was revised, and the numbering and labeling system for grades was replaced. In this ANSI standard as well as the current ISO 6846 from 1992, different contrast grades of photographic papers are expressed in terms of textural log exposure ranges. In fig.1, we see that the textural log exposure range is defined by $H_S$ - $H_T$, which is determined from the points 'S' and 'T' on the characteristic curve. In the standard, the textural exposure ranges are grouped into segments referred to as paper ranges, which are 0.1 log units wide and expressed as values from ISO R40 to ISO R190 (see fig.2c). In order to avoid decimal points in expressing the ISO paper ranges, the differences in log exposure values are multiplied by 100.

$$R = 100 \cdot \left( H_S - H_T \right)$$



| ISO paper grade | log exposure range |
|---|---|
| 0 | 1.55 |
| 1 | 1.28 |
| 2 | 1.05 |
| 3 | 0.88 |
| 4 | 0.73 |
| 5 | 0.58 |
| 6 | 0.43 |

1.70
1.40
1.15
0.95
0.80
0.65
0.50
0.35
LER

fig.2a The ANSI/ISO paper grade standards divide the log exposure range from 0.35 to 1.70 into seven grades, which are given numbers from 0 through 6.

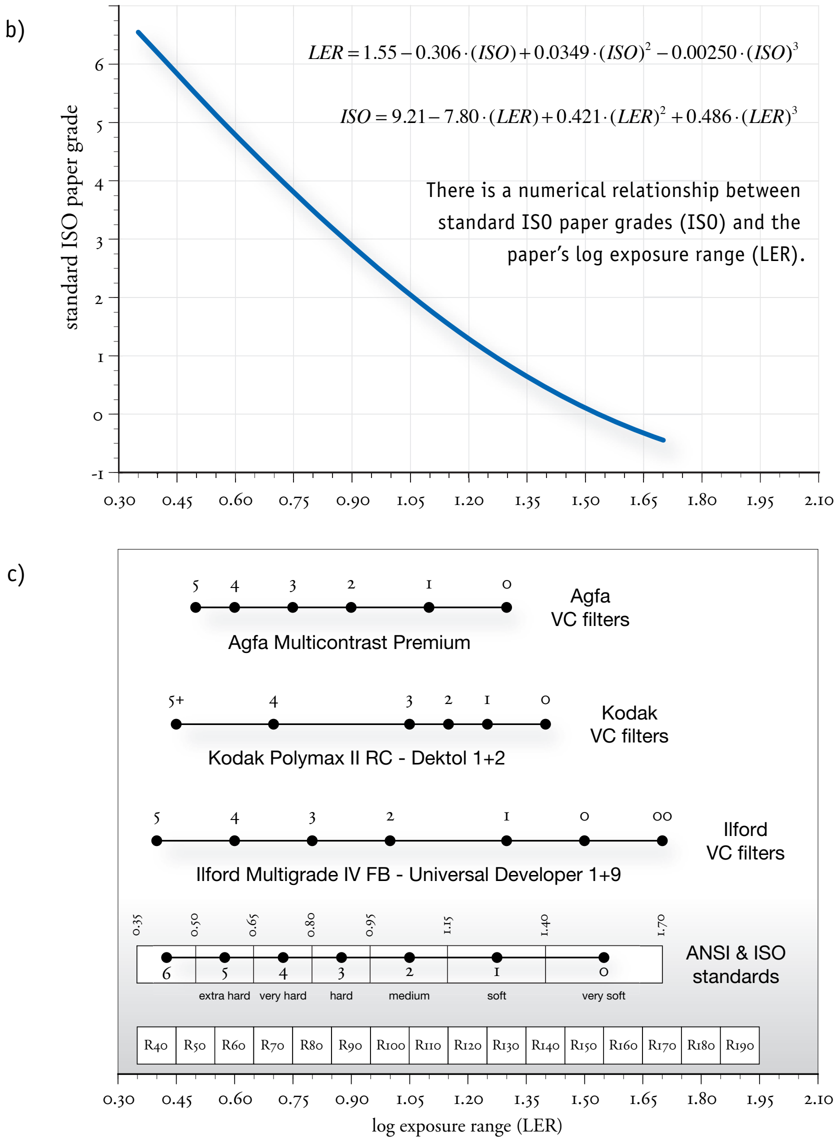


fig.2b-c The ANSI and ISO standards specify commonly used paper grades and ranges. There is a numerical relationship between standard paper grades and the log exposure range of the paper (top), but variable-contrast (VC) filter numbers have only a vague relationship to standard paper grades (bottom).

Fig.2c shows a comparison of the variable-contrast filter numbers used by Agfa, Ilford and Kodak, with the two standards. It is easy to see that there is only a vague relationship between filter numbers and the old standards. Manufacturer dependent variable-contrast (VC) filter numbers should not be confused with standard paper grades. They should always be referred to as 'filters' or 'filter numbers', to eliminate any possible misunderstanding.

In this book, we use both the paper-grading system of the old ANSI appendix and the standard ISO paper ranges, to measure and specify paper contrast, for several reasons. Manufacturers do not use their own grading systems anymore, but they have not switched completely to the new standard either. Graded papers are still available in grades from 0 to 5, even though standard paper ranges are typically also given for graded and variable-contrast papers. In addition, photographers seem to be much more comfortable communicating paper grades than paper ranges, and the confusion between filter numbers and paper grades has not helped to speed up the acceptance of standard paper ranges. Consequently, we continue to use the old paper-grading system, and we take the liberty of incorrectly referring to paper contrast, measured according to this once proposed standard, as 'standard ISO paper grades'.

## Variable-Contrast (VC) Paper

The advantages of variable-contrast paper over graded paper have made it the prime choice for many photographers today. The ability to get all paper grades from one box of paper, and even one sheet, has reduced darkroom complexity and provided creative controls not available with graded papers.

Variable-contrast (VC) papers are coated with a mixture of separate emulsions. All components of the mixed emulsion are sensitive to blue light but vary in sensitivity to green light. When the paper is exposed to blue light, all components react and contribute similarly to the final image. This creates a high-contrast image because of the immediate additive density effect produced by the different components (see fig.3). On the other hand, when the paper is exposed to green light, only the highly green-sensitive component reacts initially, while the other components contribute with increasing green-light intensity. This creates a low-contrast image because of the delayed additive density effect produced by the different components (see fig.4). By varying the proportion of blue to green light exposure, any intermediate paper contrast can be achieved.

There are several options to generate the proper blend of light required to achieve a specific paper contrast. The simplest way of controlling the color of the light is the use of filters, for example a mixture of blue and green filtered light using a Wratten 47b (deep blue) and a Wratten 58 (green) filter. However, inexpensive filter sets, optimized for VC papers and numbered from 0 to 5 in increments of 1/2, are more practical and available from most paper manufacturers. They can be used in condenser or diffusion enlargers, either below the enlarger lens or in a filter drawer above the negative. The numbers on these filters correspond only approximately to paper grades, because of a missing standard between manufacturers (see fig.2c), and because contrast differs from paper to paper and according to the type of light source used.

Finer contrast control of up to 1/10-grade increments is available with dedicated VC heads. They come with their own light source at a modest price, but are typically only calibrated for the more popular paper brands on the market. Their light source consists of either two cold cathode bulbs or two filtered halogen bulbs, both providing independent intensity controls, to alter paper contrast. With some of these products, a full contrast range may not be achievable, and contrast is unlikely to be evenly spaced.

Another popular option is a standard color enlarger, which can also be very useful to control contrast in monochrome printing. A color enlarger is typically equipped with a dichroic filter head, containing yellow and magenta filtration. The yellow filter absorbs blue and transmits green light, and the magenta filter absorbs green and transmits blue light. These filters successfully alter the contrast in VC papers, and no additional investment is required. Even minute but precise contrast changes are simple with this setup. The maximum contrast will be slightly lower than that achievable with filter sets optimized for variable-contrast paper. However, this is of little practical consequence, since full magenta filtration typically achieves a maximum standard ISO grade. Manufacturers of enlargers and papers often include tables with yellow and magenta filter recommendations to approximate the paper contrast.

To the down-to-earth monochrome printer, it is commonly of little importance which paper grade was required to fine-tune the final image as long as it helped to achieved the desired effect. However, to the discerning printer, it seems reasonable after a long darkroom session, to spend a few moments, scribbling down filter numbers or filtration settings needed to render image detail appropriately. This gives the satisfaction to pick up a negative, and start printing where you left off several months or years ago. Nevertheless, a dependable method to measure

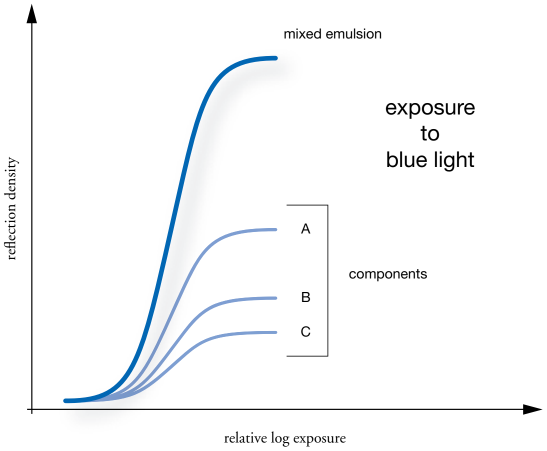


fig.3 When the paper is exposed to blue light, all components of the mixed emulsion react and contribute similarly to the final image. This creates a high-contrast image because of the immediate additive density effect produced by the different components.

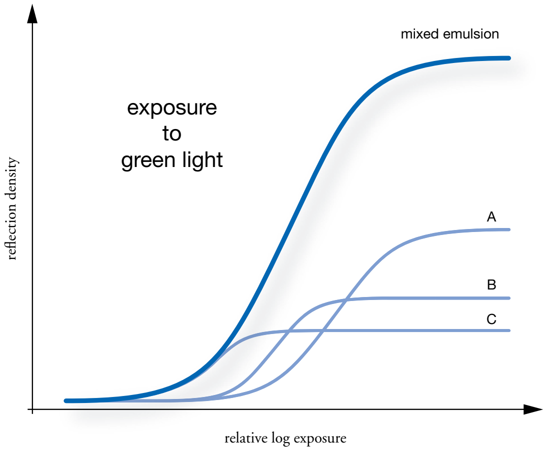


fig.4 When the paper is exposed to green light, all components react and contribute differently to the final image. This creates a low-contrast image because of the delayed additive density effect produced by the different components. (graphs based on Ilford originals)

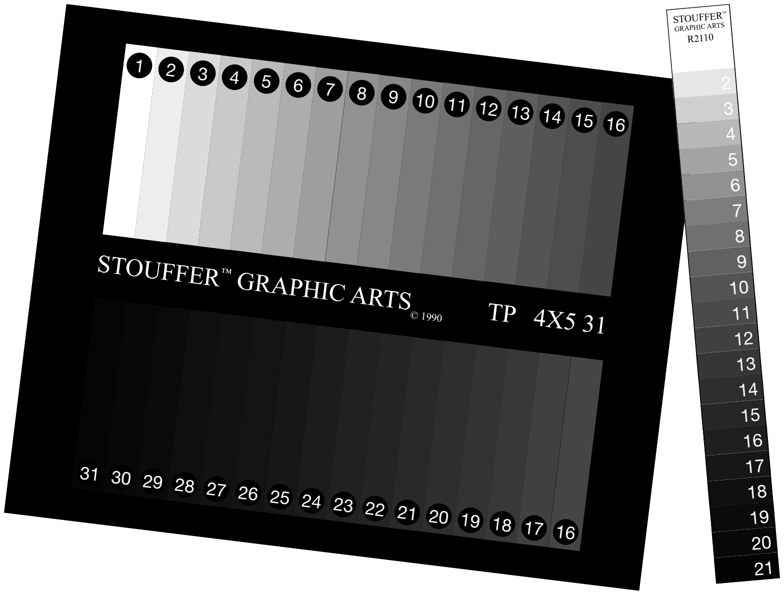


fig.5 A transmission step tablet (left) is required for the test. It should fit the enlarger for projection and have at least 31 steps. The optional reflection step tablet with 21 steps (right) is an ideal visual aid, if a densitometer is not available. Both photographic scales feature a step-to-step density increase of 0.1 and sold for about $40 a pair in 2006.

(Stouffer Graphic Arts, www.stouffer.net)

| variables | | insignificant | significant |
|---|---|---|---|
| method of control | fixed | batch variability<br>baseboard reflectivity<br>normal flare<br>reciprocity<br>latent image stability<br>drying method | light source<br>paper emulsion<br>paper surface<br>developer<br>dilution<br>temperature<br>agitation<br>time |
| | tested | | filter settings |
| | ignored | normal material aging<br>equipment aging<br>mechanical hysteresis | outdated materials<br>high flare<br>toning<br>bleaching |

fig.6 Multiple variables are responsible for the final paper contrast. How they are controlled during testing depends on how significantly they influence contrast.

standard paper contrast is needed in order to compensate for equipment and materials changes reliably, while rendering printing records less sensitive to any changes in the future.

## Equipment and Test Procedure

The equipment required to measure standard paper contrast includes a transmission step tablet, a reflection densitometer or a reflection step tablet, some graph paper and the typical darkroom equipment to expose and process photographic paper. Fig.5 shows the photographic scales supplied by Stouffer Graphic Arts. The transmission tablet on the left is used to generate the required density data. Precise measurements rely on a densitometer, but in the absence of such equipment, the reflection scale on the right, can be used as a visual aid to quantify paper contrast adequately. References to this alternative method are made at the end of this chapter.

There are many possible variables controlling the paper contrast. Fig.6 shows how the variables can be separated into their level of significance and my suggested control method for them. In this test procedure, we concentrate solely on the variables of high significance. Variables with low significance are either assumed to be fixed or are ignored. The goal of this test procedure is to determine the standard paper-contrast grades achieved with your favorite filtration method and materials. Other variables, which influence contrast significantly, need to be closely controlled and are therefore assumed to be fixed. In addition, some significant variables are considered undesirable but avoidable, and therefore, they are ignored as well. Be aware that conditions in your darkroom may change over time, necessitating an occasional control test.

For the sample test described here, the following significant variables were fixed, tested or ignored. The light source was an Omega D2V variable condenser enlarger with filter drawer. I used Kodak's Polymax VC filters, and Polymax II RC-E paper was tested. The developer used was Kodak's Dektol at a dilution of 1+2 and at a temperature of 20°C (68°F). The agitation was accomplished by constantly rocking the tray for 1.5 minutes, followed by normal processing without toning. The paper was air dried after washing.

## Generating Your Data

Select the paper and paper surface you would like to test, and have it available in a practical size, so that the transmission scale from fig.5 can be printed onto it. I always have a box of 5x7-inch paper for these types of tests in stock. Project the transmission scale, so that it fits comfortably on the paper, with some room to spare. Start with the softest filtration to produce the lowest grade possible. Expose the paper such that the whole tonal range fits on the paper. The highlight area should have several paper white wedges and the shadow area should have several maximum black wedges before any tonality is visible. Record the filtration and the exposure time on the back of the print. Then, process the paper normally, keeping development time, temperature and agitation constant. For RC papers, the development time can be fixed to 1.5 minutes, but for FB papers, the total development time should be about four to eight times (6x is normal) the 'emerging time' of the mid-tones. Ansel Adams referred to this as the Factorial Development. Repeat the process for all remaining filters or significant filtrations. Be sure to keep all other variables constant, including the exposure. This will allow us to create an exposure compensation table, as discussed in the chapter 'Exposure Compensation for Contrast Change'.

With the help of a reflection densitometer, all step wedges can be read and charted as shown in fig.7. The x-axis shows the relative log exposure values, which have equivalent log densities in the transmission tablet of fig.5. Just remember, that step number 1 has a relative transmission density of 0.0 and that number 31 has a density of 3.0. To convert the step-tablet values into paper exposures, take a step number, subtract 1, divide by (-10) and add 3.0. The result is the relative paper log exposure value of that step. The y-axis indicates the reflection densities as read with the densitometer. Use a copy of the blank record sheet from 'Tables and Templates' to collect and chart the paper density data. The result, in fig.7, shows the paper characteristic curve of our test with filter number 2.

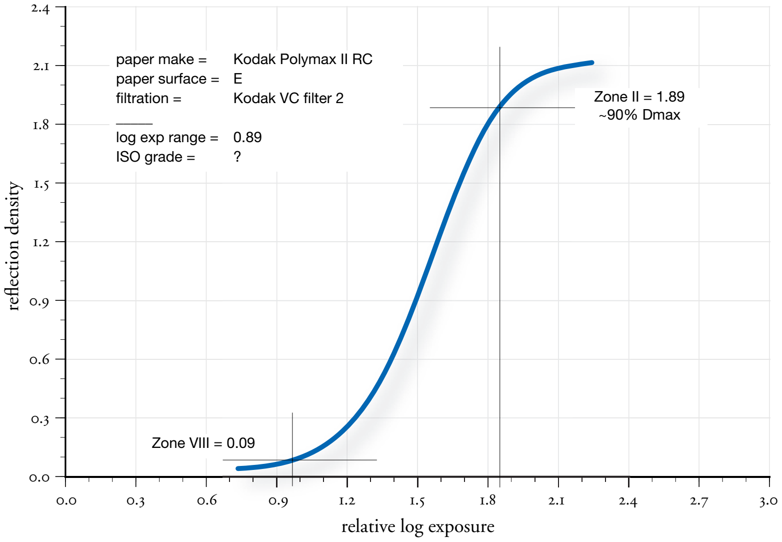


fig.7 Charting the test densities results in a typical paper characteristic curve.

## Measuring Contrast

Now, we are interested in the textural log exposure range. From fig.1, we remember that it is the delta between the first usable density and the last usable density, or also referred to as IDmin and IDmax, respectively. The ISO standard defines these two densities in relative terms, but we need absolute values for a quantitative analysis. I have chosen a reflection density of 0.09 for IDmin and 1.89 for IDmax for reasons that are explained in more detail in 'Fine-Tuning Print Exposure and Contrast'. We will use the log exposure range between 0.09 and 1.89 reflection density for the rest of this sample test.

The chapter 'Tables and Templates' includes an overlay called 'Paper Range and Grade Meter', which is a handy measuring tool based on the ANSI/ISO standard. The use of the meter overlay is shown in fig.8, as it is applied to the sample test data. The curve has been highlighted for clarity. The overlay is placed on top of the graph so the 'base+fog density' line is parallel to the grid, but tangent to the toe of the curve. The overlay is then moved horizontally until the vertical origin and IDmin (0.09) intersect with the curve in point 1. At the same time, IDmax (1.89) intersects with the curve in point 2. A vertical line drawn down from point 2 allows for the measurement of ISO grade

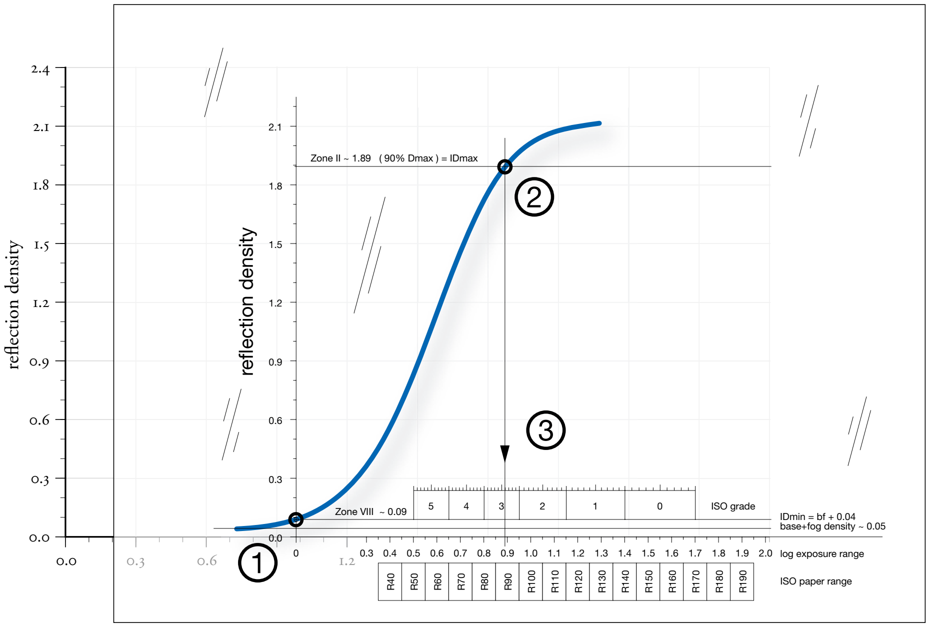


fig.8 In this example, the paper characteristic curve, obtained with a number-2 filter, is plotted and measured to determine the exposure range and ISO grade for this paper/filter combination.

**Kodak Polymax II RC**

| filter number | ISO grade | ISO range |
|---|---|---|
| -1 | 0.1 | 152 |
| 0 | 1.5 | 116 |
| 1 | 2.3 | 99 |
| 1.5 | 2.5 | 96 |
| 2 | 2.9 | 89 |
| 2.5 | 3.2 | 85 |
| 3 | 4.0 | 73 |
| 3.5 | 4.4 | 66 |
| 4 | 5.4 | 51 |
| 5 | 6.2 | 36 |

© 2002-Feb-07 Raph W. Lambrecht

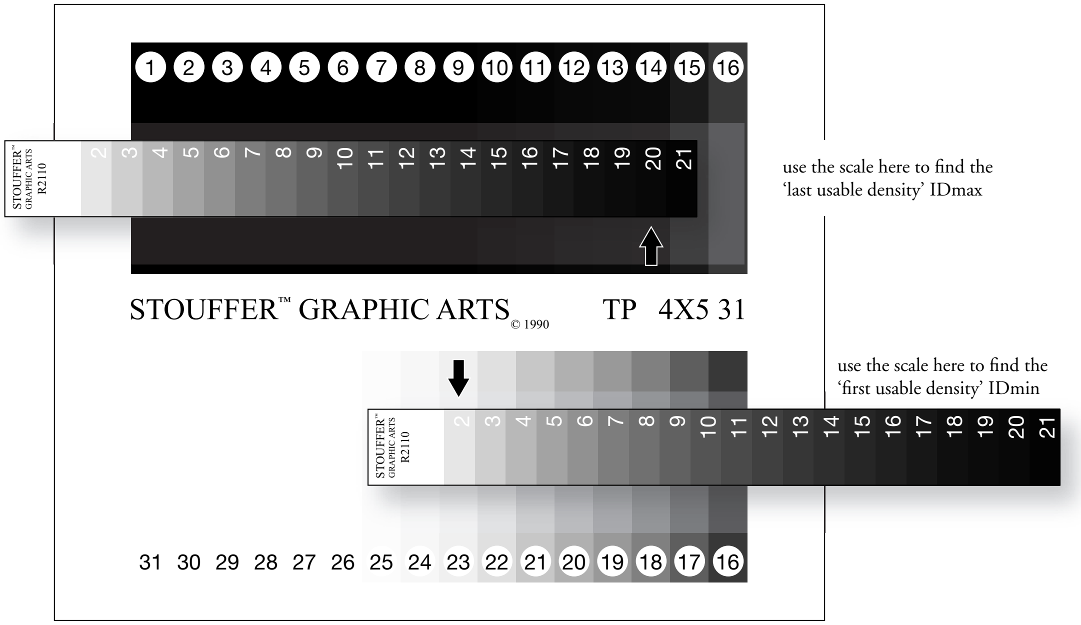
fig.9 (top) The results of all tests are compiled into a reference table, enabling us to work with standard ISO paper contrast values and objectively comparing different materials and methods.

and paper range at point 3. Fig.8 shows the overlay in this final position to take the contrast readings. For this paper and filtration, I measured an ISO grade of 2.9 and a log exposure range of 0.89 (ISO R90).

Measure ISO grade and paper range for all of your test curves and record the readings. When finished, list the results in a reference table, similar to fig.9, showing the entire test data. Now, we are able to work with standard ISO paper contrast values and objectively compare different materials and methods.

## The Alternative Method

A densitometer is still a luxury item in most amateur darkrooms. Fig.8a shows how the reflection scale from fig.5 can be used, in the absence of a densitometer, to determine the log exposure range of the sample test. Just take each filtration test, and find the wedge that has the best matching density with step number 2 and 20 on the reflection scale. These are the wedges with a reflection density of 0.15 and 1.95, respectively. I suggest conducting this evaluation in a well-lit area. Otherwise, it may be too difficult to see the difference between the dark steps. Counting the steps from highlights to shadows gives us the exposure range. In this sample test, 9 steps (23-14) are equal to a 0.9 log exposure range, since each step is equivalent to 0.1 in density increase. The bottom scales in fig.2c, or the Paper Range & Grade Meter, reveal that a 0.9 log exposure range is equivalent to an ISO paper range of R90 and a grade of just under 3. This method is not as precise as using a densitometer, but it is sufficient to get useful measurements.



use the scale here to find the 'last usable density' IDmax

use the scale here to find the 'first usable density' IDmin

fig.10 (right) A reflection scale can be used to determine the log exposure range and paper contrast adequately, if a densitometer is not available.

# Contrast Control with Color Enlargers

## Calibration of dichroic heads to ISO paper grades

The advantages of variable contrast paper over graded paper have been discussed in previous chapters. The most important benefit is the ability to get all paper grades from a single sheet of paper, which provides creative controls otherwise not available. All this is possible, because variable contrast (VC) papers are coated with a mixture of separate emulsions, which have different sensitivities to blue and green light. By varying the ratio of the blue to green light exposure, any intermediate paper contrast can be achieved.

Cistercian Abbey of Fontenay
Passage to the Cloister, France 2006

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50039-9

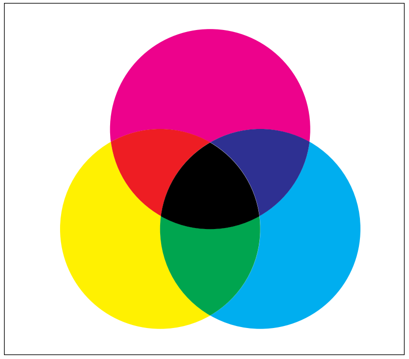
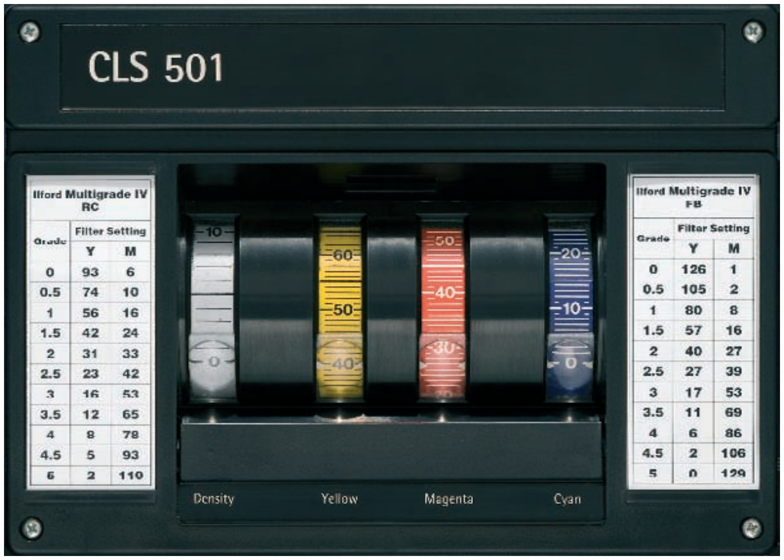


fig.1 A subtractive color system starts with white light and uses yellow, magenta and cyan filters in appropriate concentrations to control the amounts of blue, green and red light respectively.

Working with a color enlarger is a convenient way to generate a proper blend of green and blue light in order to achieve a specific paper contrast. Color enlargers are designed to provide a subtractive color system, and for that reason, they are typically equipped with a dichroic filter head, containing yellow, magenta and cyan filtration. A subtractive color system starts with white light and uses yellow, magenta and cyan filters in appropriate concentrations to control the amounts of blue, green and red light respectively (fig.1). The yellow filter absorbs blue and transmits red and green light, and the magenta filter absorbs green and transmits blue and red light. The red-light transmission of both filters is of no consequence to monochrome printing, because VC papers are insensitive to red light, but the yellow and magenta filter settings also control the amount of green and blue light transmitted. This successfully alters the contrast in VC papers, and even minute but precise contrast changes are easily made with either filter or a combination of the two filter settings.



Ilford Multigrade IV
RC

| Grade | Filter Setting | |
|---|---|---|
| | Y | M |
| 0 | 93 | 6 |
| 0.5 | 74 | 10 |
| 1 | 56 | 16 |
| 1.5 | 42 | 24 |
| 2 | 31 | 33 |
| 2.5 | 23 | 42 |
| 3 | 16 | 53 |
| 3.5 | 12 | 65 |
| 4 | 8 | 78 |
| 4.5 | 5 | 93 |
| 6 | 2 | 110 |

Ilford Multigrade IV
FB

| Grade | Filter Setting | |
|---|---|---|
| | Y | M |
| 0 | 126 | 1 |
| 0.5 | 105 | 2 |
| 1 | 80 | 8 |
| 1.5 | 57 | 16 |
| 2 | 40 | 27 |
| 2.5 | 27 | 39 |
| 3 | 17 | 53 |
| 3.5 | 11 | 69 |
| 4 | 6 | 86 |
| 4.5 | 2 | 106 |
| 5 | 0 | 129 |

fig.2 A color enlarger with dichroic filters is a very useful piece of equipment for monochrome printing. The yellow and magenta filters can be used to fine-tune the paper contrast in VC papers, and even minute but precise contrast changes are simple by altering the two filter settings. A custom calibration allows precise paper grade settings in accordance with ISO standards.

The remaining cyan filter, on the other hand, is of little use to monochrome workers, because cyan is a mixture of green and blue light, and consequently, cyan filtration absorbs red and only transmits green and blue light. VC papers are sensitive to green and blue, but since cyan filtration alters their contribution in equal amounts, there is little reason to use cyan filtration for monochrome printing, unless its minute neutral-density effect (1/3 stop max) is utilized to fine-tune the print exposure. Even if we ignore the cyan filter altogether, the possibility of yellow and magenta filtration makes a color enlarger a very useful piece of equipment to control the contrast in monochrome printing. Note that the maximum contrast is usually slightly lower than that achievable with customized filter sets, which are optimized for variable-contrast papers. Fortunately, this is of little practical consequence, since full magenta filtration typically achieves maximum standard ISO grades of 4.5 to 5.

Manufacturers of enlargers and papers often include tables with yellow and magenta filter recommendations to approximate the paper contrast. However, these recommendations are to be taken with a grain of salt, because they are based on assumptions about the light source and papers used. A custom calibration allows precise paper-grade settings in accordance with ISO standards. This calibration turns the dichroic color head into a precision VC diffusion light source, ideally suited for flexible and consistent monochrome printing.

Many casual printers see no need for this level of precision. The published filter suggestions for dichroic color heads vary, but mostly by less than one grade. The technique of simply dialing in more yellow or magenta to adjust the contrast works for most darkroom enthusiasts. However, calibrated dichroic color heads provide a few real advantages over other methods and are favored by discriminating workers. By using standard ISO grades, the future validity of printing records is protected against upcoming material and equipment changes. Once an ISO grade is recorded and filed with the negative for future use, prints with identical overall contrast can be made on any material, even in years to come. In addition, contrast changes are consistent through use of standard ISO grades. Going up or down a grade always yields the same change in contrast on any material and with any equipment. VC filters and VC heads do not offer this level of flexibility, precision and control. They are made for today's materials and may not work reliably with future products.

| **test settings** | | |
|---|---|---|
| **test number** | **filter setting** | |
| | **Y** | **M** |
| **1** | **130** | **0** |
| **2** | **110** | **2** |
| **3** | **95** | **4** |
| **4** | **80** | **8** |
| **5** | **65** | **12** |
| **6** | **50** | **20** |
| **7** | **35** | **30** |
| **8** | **20** | **50** |
| **9** | **10** | **70** |
| **10** | **4** | **95** |
| **11** | **0** | **130** |

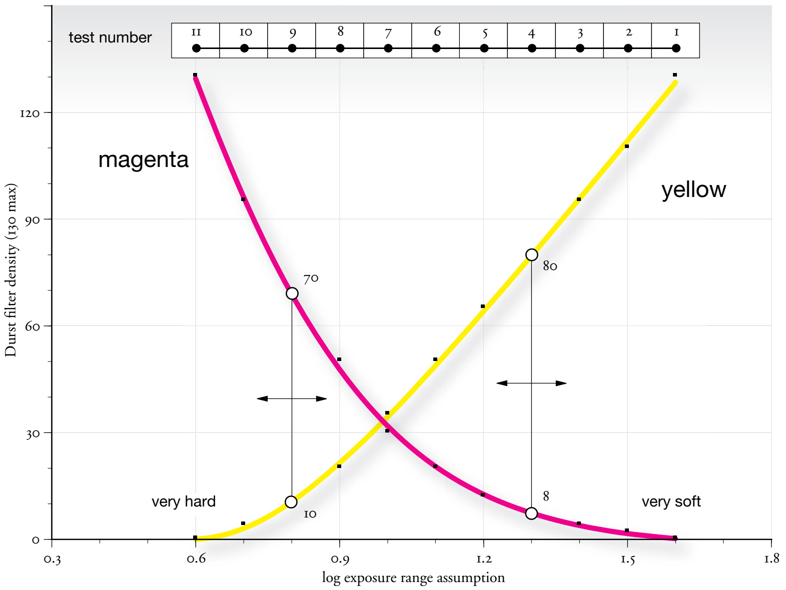


fig.3 These are my recommended test values for a color head with 130 units of maximum density, listed in form of a table (far left) and illustrated in form of a graph (left). Eleven Y-M filter pairs cover the range from the softest to the hardest grade. The actual log exposure range for each filter pair depends on the paper tested, but the filter combinations are fixed to maintain an almost constant exposure, regardless of filtration changes.

## Test Procedure

The goal in creating your own custom calibration is to produce standard paper contrast grades with color enlarger filter settings. The sample calibration described here, was conducted for the following significant variables. The light source was the diffusion dichroic color head CLS 501, fitted to a Durst L1200 enlarger. The Y-M-C filters have continuous density settings from 0 to 130. The paper tested was Kodak's Polymax II RC-E, which is resin-coated (RC) and has a surface often referred to as 'luster' or 'pearl'. The developer used was Kodak's Dektol at a dilution of 1+2 and at a temperature of 20°C (68°F). The agitation was accomplished by constantly rocking the tray for 90 seconds, followed by normal processing without toning. The paper contrast was determined following the technique described in 'Measuring Paper Contrast'.

This test procedure follows the general printing rule of 'expose for the highlights and control the shadows with contrast'. After finding the correct exposure for the significant highlights, the paper contrast is altered until the image shadows exhibit the desired level of detail and texture.

| **filter values** | | |
|---|---|---|
| **Durst** (max 130) | **Durst** (max 170) | **Kodak** (max 200) |
| 0 | 0 | 0 |
| 10 | 15 | 15 |
| 20 | 25 | 30 |
| 30 | 40 | 45 |
| 40 | 50 | 60 |
| 50 | 65 | 75 |
| 60 | 80 | 90 |
| 70 | 90 | 110 |
| 80 | 105 | 125 |
| 90 | 120 | 140 |
| 100 | 130 | 155 |
| 110 | 145 | 170 |
| 120 | 155 | 185 |
| 130 | 170 | 200 |

fig.4 Different filtration systems are available, and they use different filtration values. This conversion table shows equivalent values for the most common systems.

Single and dual-filter settings are two possible ways to modify the paper contrast. The single-filter method uses either yellow (Y) or magenta (M) filtration, but never both. The dual-filter method, as its name implies, always uses a combination of both filtrations. The single-filter method has the benefit of minimizing exposure times, by minimizing the total filter density. It has the disadvantage, however, that every contrast modification must be compensated by a substantial exposure adjustment in order to achieve a consistent highlight density. The dual-filter method, on the other hand, uses Y and M filtration in harmony in an attempt to maintain exposure, while altering paper contrast. The disadvantage is that the combined filter density reduces the light output, resulting in longer exposure times. This disadvantage

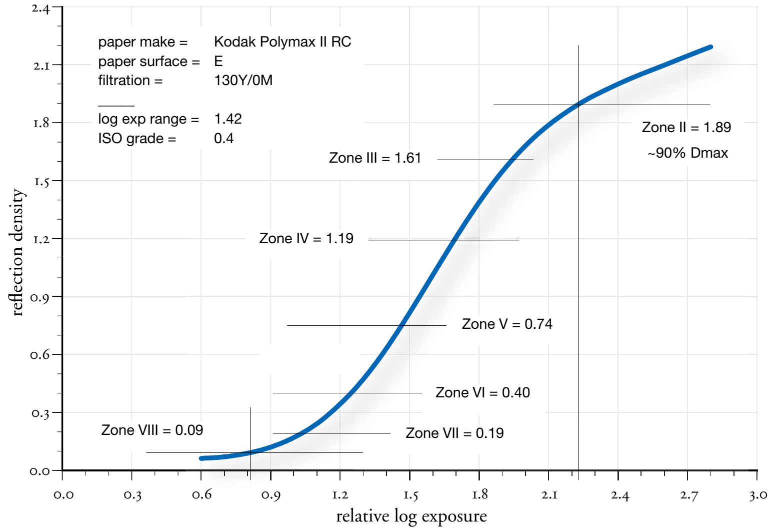


fig.5 The results for test 1 are plotted to determine the softest exposure range.

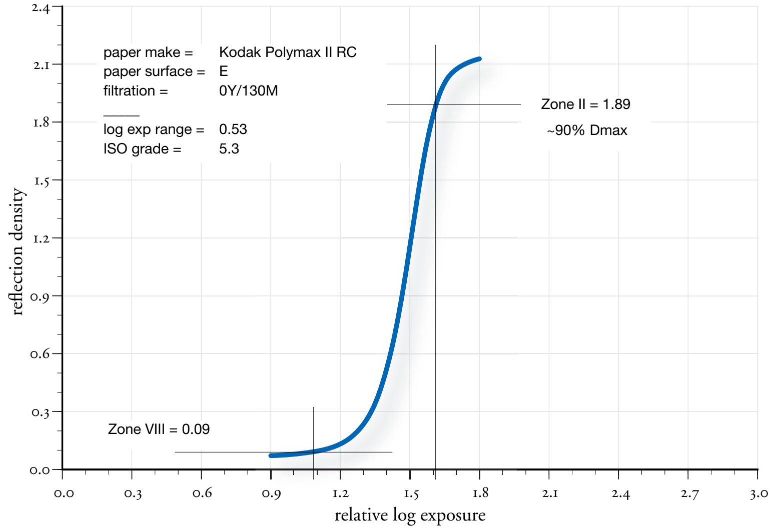


fig.6 The results for test 11 are plotted to determine the hardest exposure range.

has proven to be insignificant in my work, and the promise of almost consistent highlight exposure is just too good to give up on. Therefore, this test uses the dual-filter method exclusively to calibrate a dichroic color enlarger head.

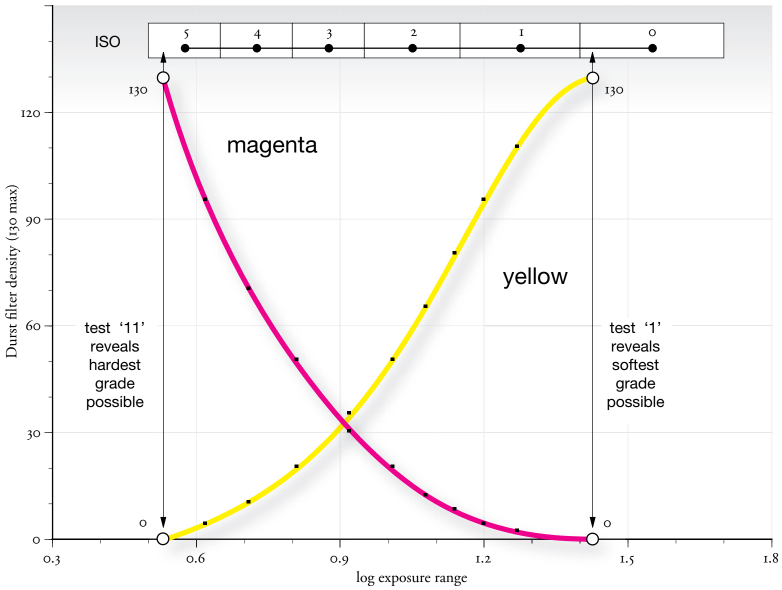
The task at hand is to determine the required amount of Y and M to achieve a certain paper contrast, while simultaneously maintaining adequate highlight exposure. Fortunately, we benefit from the research conducted by Agfa, Ilford and Kodak in this field. Fig.3 shows my recommended test settings for a color head calibration utilizing Durst filtration values, with up to 130 units of maximum density, listed in form of a table and illustrated in form of a graph. Eleven Y-M filter pairs evenly cover the assumed exposure ranges from the softest to the hardest grade. Some enlargers use different maximum density values than Durst, but it is not too difficult to choose proportional values. Fig.4 provides a conversion table for the most common filtration systems used.

## Generating the Data

Conduct eleven tests with varying yellow/magenta filtration as shown in fig.3. Determine the paper contrast from each test following the technique described in 'Measuring Paper Contrast'. Start with the filter settings for test 1 (130Y/0M), to produce the lowest grade possible. Expose the paper in a way that the whole scale fits on the paper. The highlight area should have several paper white wedges, and the shadow area should have several maximum black wedges before any tonality is visible. Record the filter settings and the exposure time on the back of the print. Then, process the paper normally, while keeping development time, temperature and agitation constant. Repeat the process for the remaining ten tests at their different filter settings. Keep the exposure time constant, so an exposure compensation table can be created later. See 'Exposure Compensation for Contrast Change' to make such a table. Once the data has been collected and charted, it will look similar to fig.5 (test 1) and fig.6 (test 11). The x-axis shows the relative log exposure values and the y-axis indicates the reflection densities as read with the densitometer. The results are typical paper characteristic curves, and the test evaluation clearly shows that magenta filtration results in greater paper contrast than yellow filtration and that paper contrast can be altered by combining the two filters.

## Calibration

Chart the results from the eleven tests on a sheet of graph paper or with the help of a computer. This allows us to select any standard ISO paper grade or range, for the paper tested, with precision and ease. In fig.7, we see that test 1 returned a log exposure range of 1.42 (grade 0.4) for the filter combination (130Y/0M). The filtration is aligned with the log exposure range,



**Kodak Polymax II RC**

| ISO grade | filter setting Y | M |
|---|---|---|
| 0 | - | - |
| 0.5 | 129 | 0 |
| 1 | 111 | 2 |
| 1.5 | 84 | 8 |
| 2 | 59 | 15 |
| 2.5 | 40 | 25 |
| 3 | 27 | 37 |
| 3.5 | 18 | 51 |
| 4 | 11 | 68 |
| 4.5 | 6 | 88 |
| 5 | 3 | 112 |

© 2006-May-10 Ralph W. Lambrecht

fig.7 (far left) A dual-filtration chart illustrates all test results, and the filtration for any log exposure range can easily be determined from it. A small table (left) is useful for listing the required filtration of the major paper grades for future use.

as indicated by the arrows on the right-hand side of the graph. Test 11 returned a log exposure range of 0.53 (grade 5.3) for the filter combination (0Y/130M). This data is shown by the arrows on the left-hand side. Plot the point pairs for all tests this way, and draw two smooth lines through the points to create a curve for magenta and yellow filtration.

You can now determine any filter combination required to simulate any standard ISO paper grade or range. A vertical line connects paper grade with Y-M filtration. A small table, as shown on the right in fig.7, helps to list the filtrations for the typical paper grade increments. I keep the ones for my favorite papers taped to the front of my enlarger head, so they are always at hand.

## Exposure Variations

Switching from one grade of paper to another may require a change in print exposure. The dual-filter method is far more consistent in print exposure than the single-filter method, but references to print exposure deviations need to be expressed in respect to target density. The dual-filter method delivers an almost constant exposure for Zone-V densities throughout the entire paper contrast range. However, the highlight exposures (Zone VIII) vary for about one stop, and the shadow exposures (Zone II) vary for about two stops (log 0.3 = 1 stop).

Fig.8 summarizes these exposure variations from Zone II to VIII. The relative log exposure was plotted for all zones in all eleven tests against their respective ISO grades. A constant exposure would be represented by a perfectly vertical line. Zone V comes closest to that condition. All other zones deviate enough to require exposure compensation when changing paper contrast. This graph helps us to draw a few conclusions. First, paper, enlarger, light source and filter manufacturers need to tell us what target density they are referring to when they promise a filtration system to provide constant exposure throughout the contrast range. Second, the dual-filter method provides an almost constant exposure only for Zone-V densities. Highlight and shadow exposures, on the other hand, change independently throughout the contrast range. Improving this filtration method to provide more consistent exposures for Zone VII or VIII, would make it more valuable to us and support our printing rule 'expose for the highlights and control the shadows with contrast'.

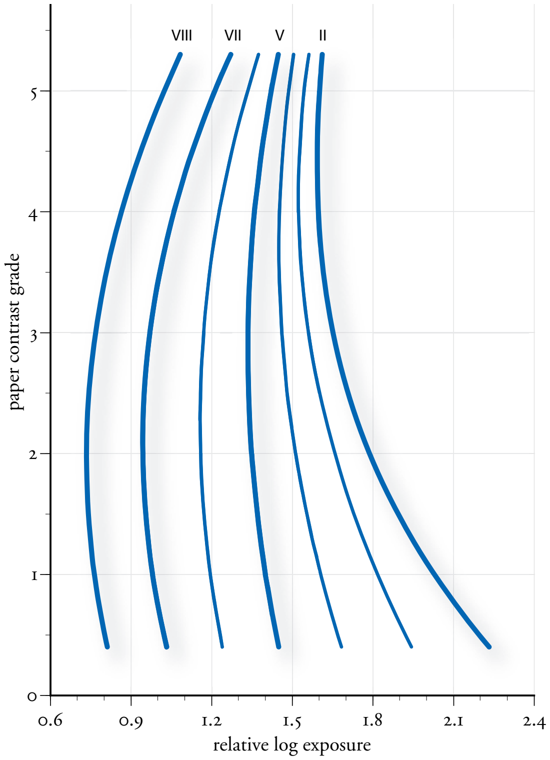


fig.8 The exposure required to create a given paper density changes with paper grade. A constant exposure would be represented by a perfectly vertical line.

In the past, two different systems were proposed to address this challenge. The first system is based on the least exposure required. It is demonstrated in fig.9, which concentrates purely on Zone-VIII exposures. The exposure is roughly within 1/12 stop and, therefore, nearly constant from grade 1 to grade 3. Outside of this range, and particularly towards the harder grades, the exposure drops off significantly. The least exposure required to create a Zone-VIII density, is close to an ISO grade 2. The exposure can be made constant by adding extra exposure time to all other grades. The second system, based on the most exposure required, is demonstrated in fig.10. The most exposure required, to create a Zone-VIII density, is at grade 5. The exposure could be made constant by adding a certain neutral density to all other grades.

I favor the least exposure system in fig.9 for my work for several reasons. The burden of extra density, and ultimately exposure time, to synchronize a rarely used grade 5, seems like a waste. One author has proposed adding the required neutral density in the form of Y-M filtration. Fig.10 clearly reveals this attempt is doomed to failure. Soft-grade filtration requires far less exposure than grade-5 filtration. Neutral density (or cyan filtration) can, of course, be added to lengthen the soft-grade exposures, but not with Y-M filtration, because the Y filtration is already at or around its maximum at soft grades.

Calibrating color enlargers to control print contrast consistently is a useful exercise for monochrome workers. It enables confident ISO-grade selection and makes for more meaningful printing records.

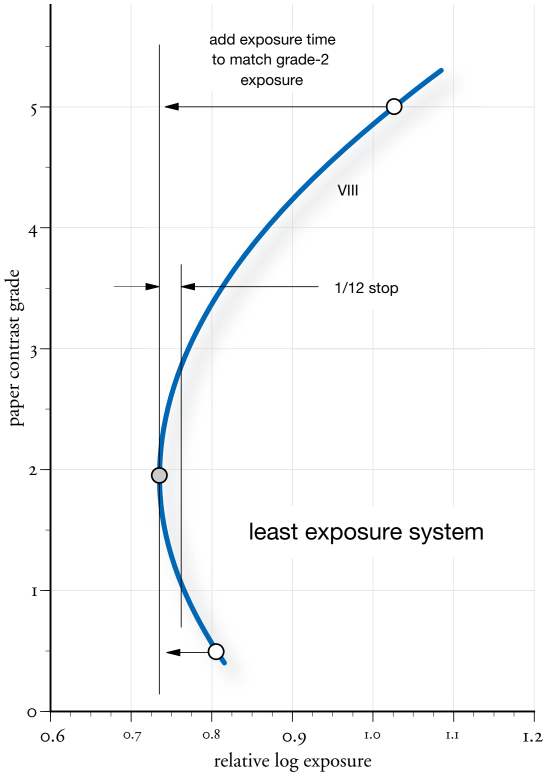


fig.9 This illustration is similar to fig.8, but it shows the amount of additional exposure required to match the Zone-VIII exposure at grade 2.

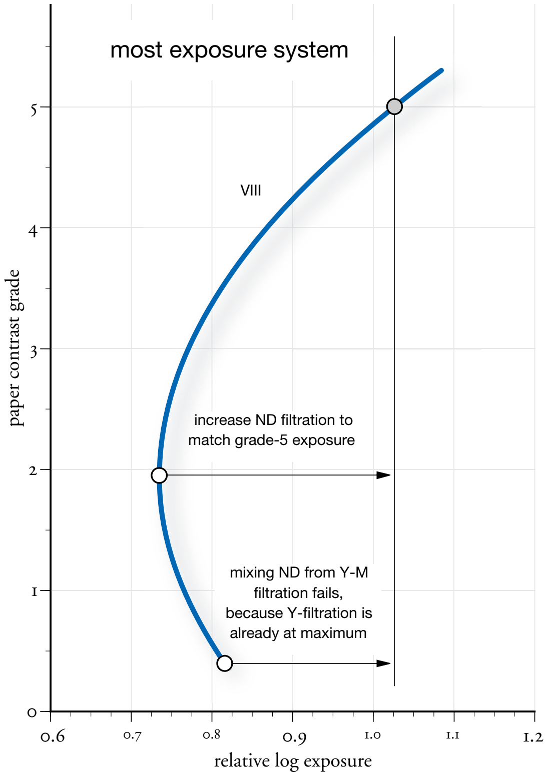


fig.10 This illustration is similar to fig.8, but it shows the amount of additional filtration required to match the Zone-VIII exposure at grade 5.

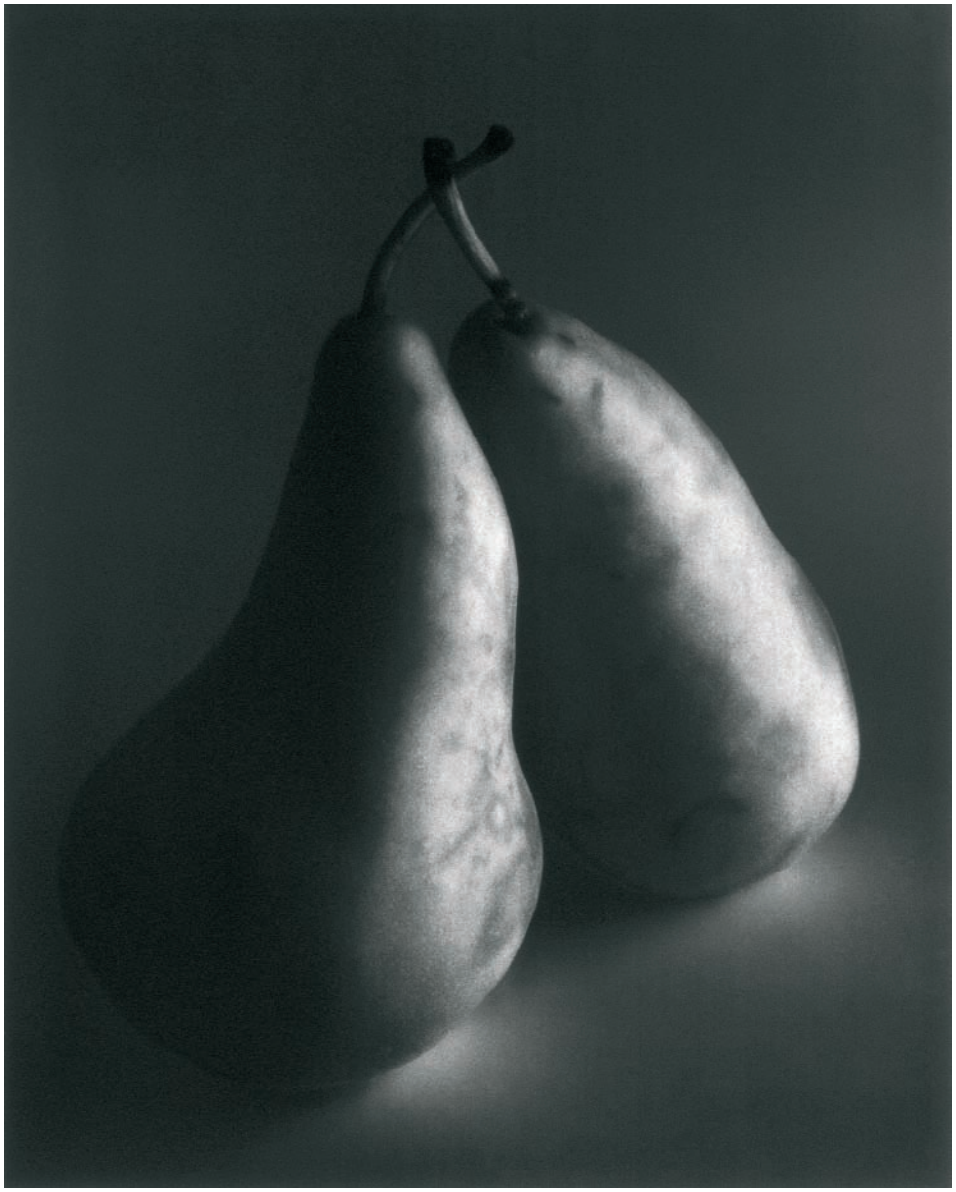
# Exposure Compensation for Contrast Change

## How to chase the moving target of exposure

Controlling significant highlight densities with print exposure, and fine-tuning image shadows with paper contrast adjustments, is standard practice for experienced darkroom workers, because it is a successfully proven printing method. The technique would be easier to implement if changes to print exposure and paper contrast could be made without affecting each other. This is the case with print exposure, because changing the exposure does not modify the print contrast at all. Unfortunately, it is not the case for paper contrast changes. Any significant modification in paper grade or filtration is typically accompanied by an unwanted change in highlight density. This often makes it necessary to support a paper contrast change with a compensating exposure adjustment.

Some paper and filter manufacturers advertise that, when using their products, paper contrast changes can be accomplished without the need for an exposure correction. To understand this claim, we need to be aware that any reference to constant print exposure must be made in terms of target density. The ISO paper standard (see fig.1) defines the 'speed point' as the exposure required to achieve a print density of 0.6 above base+fog. Paper manufacturers use the speed point to determine the paper sensitivity.

Fig.2 shows a case where the contrast of a variable-contrast paper is modified through a set of contrast filters. In this example, filters numbered 1-4 need exactly the same exposure to produce a speed-point density of 0.6, and filters 4-5 require an additional stop to do the same. Within the two filter groups, the claim for constant exposure seems to be correct. However, providing a constant paper exposure for this speed-point density may satisfy the ISO standard, but it does not support established, and successfully proven, printing methods. A speed-point density of 0.6 is far too dark for most print highlights, and therefore, an



© 2002 by Hisun Wong, all rights reserved

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50040-5

fig.1 (right) The ISO standard defines the paper 'speed point' at 0.6 above base+fog density, which is used by manufacturers to determine the paper sensitivity.

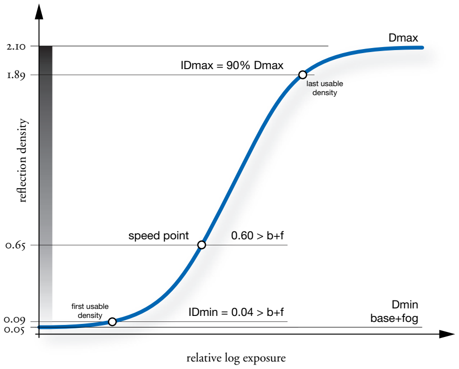
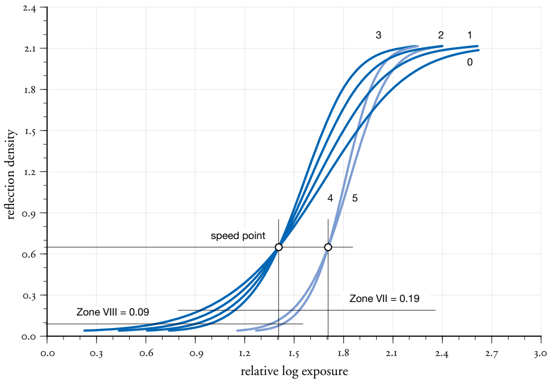


fig.2 (far right) Most variable-contrast filters are designed to keep speed-point-density exposures constant. This, however, requires an exposure correction for the more typical print highlight densities, whenever the paper contrast is modified.



exposure correction is required for the more typical print highlight densities whenever the paper contrast is modified. For example, as seen in fig.2 at a target density of 0.09 (Zone VIII), the characteristic curves intersect the target density line at increasing exposure values, which indicates that for this set of contrast filters, the required exposure increases with paper contrast. The same is true for a target density of 0.19 (Zone VII). What we need is a simple method to maintain significant highlight densities whenever we would like to optimize the paper contrast.

When a print has been optimized for its highlight exposure, and it is evident that more or less contrast is needed to optimize the shadows as well, using a table similar to fig.4 is an efficient way to determine an appropriate exposure correction for the new contrast setting in order to keep important highlight densities constant. For example, in fig.4, locate the row labeled with the old paper contrast, move along that row to the column labeled with the new paper contrast, and use the resulting factor to multiply it with the old exposure time in order to get the new exposure time. A simple test provides all the data necessary to prepare such a customized exposure correction table for our favorite papers, variable-contrast filters or calibrated color enlarger settings.

To collect the required data, set your enlarger to a fixed height, close the aperture by a few stops, and without a negative in the carrier, prepare a light-gray test strip for each paper grade or filtration. This is best done in half-grade increments, if possible. The test print in fig.3 shows an example prepared with a color enlarger and a calibrated grade-3 filtration. The purpose of the test is to find the exposure time required to produce the same highlight density with each paper-contrast setting. A good strategy is to bracket slightly different exposures around a specific target density. Choosing a density value of 0.09 for Zone VIII is a good starting point.

The test exposure increments must be fine enough to find the target density with confidence, and they must be long enough to calculate reliable results. I suggest 1/12 stop increments around a 10-second exposure. Be sure to write all test parameters, such as paper grade and exposure times, on the back of each print before wet processing. Now, wait until all test prints have fully dried, transfer the test parameters to the front of the prints and start your examination.

A densitometer is a useful piece of equipment to precisely measure actual print densities, but for this particular test, it is more important to compare the exposure times of the same highlight density between contrast settings than to know the actual density values. As long as you can reliably determine the exposure times required to maintain a constant highlight density, you can make a reliable exposure correction table.

Starting with the lowest contrast setting, take the test print and find the gray bar closest to the target

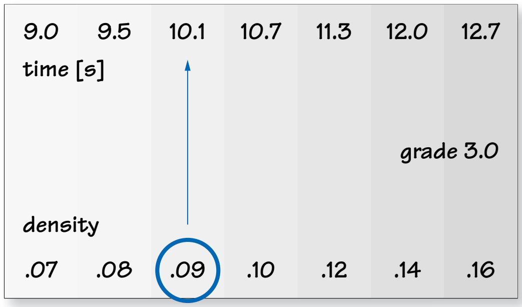


fig.3 For each contrast setting, a test print is prepared in order to determine the exposure time required to maintain a constant highlight density.

highlight density. Transfer its exposure time to a blank version of the table in fig.4, and enter the number into the gray box at the neutral intersection of old and new paper contrast. Our sample reading for grade 3 (10.1 s from fig.3) was entered at the intersection of old and new grade-3 contrast. Do the same for the remaining test prints until all gray boxes along the diagonal are filled with the exposure time required to reach the target density at that contrast setting.

To fill in the rest of the table, you need to calculate the differences in exposure time between contrast settings. I suggest doing this for up to two grades in each direction. For example, if 9.0 seconds are required to produce the target highlight density at grade 2.5, and 10.1 seconds are required to do the same for grade 3, then switching from grade 2.5 to 3 demands that the old exposure time is multiplied by a factor of 1.12 (10.1/9.0) in order to maintain consistent highlight densities. A simple computer spreadsheet may accomplish the laborious task of performing all calculations.

The table in fig.5 benefits from the same test data as fig.4 and shows the same exposure corrections but in a different unit. Fig.5 identifies the number of 1/12 stop adjustments required to support the change, which makes it more convenient for darkroom workers who are familiar with f/stop timing. In terms of 1/12 stops, the exposure adjustment (Δt) is given by:

$$\Delta t_{\frac{1}{12}stop} = \frac{\log\left(\frac{t_{new}}{t_{old}}\right)}{\log 2}\cdot 12$$

where '$t_{new}$' and '$t_{old}$' are the exposure times for the new and old contrast settings, respectively.

You may use whichever table best suits your way of working, because they fundamentally work the same. Imagine that you have a print with the proper highlight exposure, but you would like to change the contrast while maintaining the exposure for the highlights. Select the current contrast setting on the vertical axis and find the target contrast on the horizontal axis. You will find the suggested exposure increase or decrease at the intersection of the two contrast settings. This makes contrast optimizations much more convenient and should eliminate any possible hesitation to do so in the first place.

| old contrast | new contrast | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **VIII** | **0** | **0.5** | **1** | **1.5** | **2** | **2.5** | **3** | **3.5** | **4** | **4.5** | **5** |
| **5** | | | | | | | 0.71 | 0.79 | 0.89 | 0.94 | *14.3* |
| **4.5** | | | | | | 0.67 | 0.75 | 0.84 | 0.94 | *13.5* | 1.06 |
| **4** | | | | | 0.63 | 0.71 | 0.80 | 0.89 | *12.7* | 1.06 | 1.13 |
| **3.5** | | | | 0.67 | 0.71 | 0.80 | 0.89 | *11.3* | 1.12 | 1.19 | 1.27 |
| **3** | | | 0.70 | 0.75 | 0.79 | 0.89 | *10.1* | 1.12 | 1.26 | 1.34 | 1.42 |
| **2.5** | | 0.79 | 0.79 | 0.84 | 0.89 | *9.0* | 1.12 | 1.26 | 1.41 | 1.50 | |
| **2** | 0.84 | 0.89 | 0.89 | 0.95 | *8.0* | 1.13 | 1.26 | 1.41 | 1.59 | | |
| **1.5** | 0.88 | 0.93 | 0.93 | *7.6* | 1.05 | 1.18 | 1.33 | 1.49 | | | |
| **1** | 0.94 | 1.00 | *7.1* | 1.07 | 1.13 | 1.27 | 1.42 | | | | |
| **0.5** | 0.94 | *7.1* | 1.00 | 1.07 | 1.13 | 1.27 | | | | | |
| **0** | *6.7* | 1.06 | 1.06 | 1.13 | 1.19 | | | | | | |

**exp factor**
Ilford
Multigrade IV FB
MGF.1K
© 2005-Jan-01 by Ralph W. Lambrecht

fig.4 The exposure data for significant highlight densities (here for Zone VIII) is used to create an exposure correction table. Expressing the exposure adjustments as exposure time factors is useful with regular linear timers. If needed, a similar table may be created for Zone VII highlight densities.

| old contrast | new contrast | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **VIII** | **0** | **0.5** | **1** | **1.5** | **2** | **2.5** | **3** | **3.5** | **4** | **4.5** | **5** |
| **5** | | | | | | | -6 | -4 | -2 | -1 | *14.3* |
| **4.5** | | | | | | -7 | -5 | -3 | -1 | *13.5* | 1 |
| **4** | | | | | -8 | -6 | -4 | -2 | *12.7* | 1 | 2 |
| **3.5** | | | | -7 | -6 | -4 | -2 | *11.3* | 2 | 3 | 4 |
| **3** | | | -6 | -5 | -4 | -2 | *10.1* | 2 | 4 | 5 | 6 |
| **2.5** | | -4 | -4 | -3 | -2 | *9.0* | 2 | 4 | 6 | 7 | |
| **2** | -3 | -2 | -2 | -1 | *8.0* | 2 | 4 | 6 | 8 | | |
| **1.5** | -2 | -1 | -1 | *7.6* | 1 | 3 | 5 | 7 | | | |
| **1** | -1 | 0 | *7.1* | 1 | 2 | 4 | 6 | | | | |
| **0.5** | -1 | *7.1* | 0 | 1 | 2 | 4 | | | | | |
| **0** | *6.7* | 1 | 1 | 2 | 3 | | | | | | |

**1/12 f/stop**
Ilford
Multigrade IV FB
MGF.1K
© 2005-Jan-01 by Ralph W. Lambrecht

fig.5 Another version of the exposure correction table above presents the same data in f/stop units. Expressing the exposure adjustments in multiples of 1/12-stop exposure corrections is more convenient with sophisticated f/stop timers.

(table design based on an original by Howard Bond)

# Basic Split-Grade Printing

## Alternative contrast control with VC papers

fig.1 final print

Split-Grade printing is a method by which a separate soft and hard exposure is used to make a print with an overall intermediate contrast setting on variable-contrast paper. Since photography shows some correlation between measurement and subjective evaluation, we can dispel some myths concerning this technique in this first part and ready ourselves for the more interesting uses in the next chapter. As a printing technique, split-grade printing is remarkable, for it can offer even and fine contrast control with either normalized shadow or highlight exposure and with relatively short exposures. Although at first it can feel cumbersome, with a little practice it can find favor with tricky printing situations. In photography there can be many tools and methods used to achieve the final result. As with many art forms, each method has its devotees and denouncers. While this makes for entertaining discussion, it does rather miss the point. Split-Grade printing is one of those alternative techniques that works all of the time for some and some of the time for all. After all, every B&W photographic printing technique uses blue and/or green light to expose the printing paper. So why do some printers prefer one grade controlling technique to another? What rules do they use to judge?

### VC Filter Techniques

Split-Grade printing only works with variable-contrast (VC) paper. These papers use the relative energy of blue and green exposure to change the effective contrast of the print. There are several ways of controlling these exposures. In addition to the methods described in the chapter ‘Contrast Control with Color Enlargers’, we note that a color head allows fine contrast control but has the disadvantage of being unable to reproduce the highest filter settings. However, as we shall recognize later, there are

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50041-7

also some ergonomic disadvantages (all that messing about to change the dials in-between exposures) that can discourage some printers from multiple contrast grade printing with color enlargers.

Alternatively, under-lens contrast filter kits or specialized variable-contrast heads offer quick contrast changes over a wide range with even grade spacing, sometimes at the expense of fine control around the 'normal' grades. Another option is to use a mixture of blue and green-filtered light, either in the form of a Wratten 47b (deep blue) and 58 (green) filter or with dual cold-cathode bulbs using separate lamp intensity controls to alter the contrast setting.

As previously described, split-grade printing is a technique where the overall print exposure is made of two separate controlled exposures. Normally, one exposure is made at the highest available contrast setting and the other at the lowest. Each exposure on its own would either give a very hard or very soft print. These two components can be formed by either:

1) changing filtration with a single light source and using two separate, timed exposures,
2) altering the intensity of two different colored light sources and printing the combination for a common time or
3) two light sources printed separately.

For my own work, I prefer the speed and consistency of the Ilford under-lens filter kit, using just the 00 and 5 filters in combination with a StopClock dual-channel enlarger timer. In any other darkroom, depending upon the type of color head being used, I use full magenta filtration and about 3/4 full yellow filtration. This works fine with almost all enlarger light sources except for blue rich cold-cathode light sources for which I adopt the opposite strategy of 3/4 magenta and full yellow filtration to give a similar range. As long as I am consistent within a printing session, the actual filter values are not critical, since, as we shall see later, knowing the contrast setting is almost irrelevant.

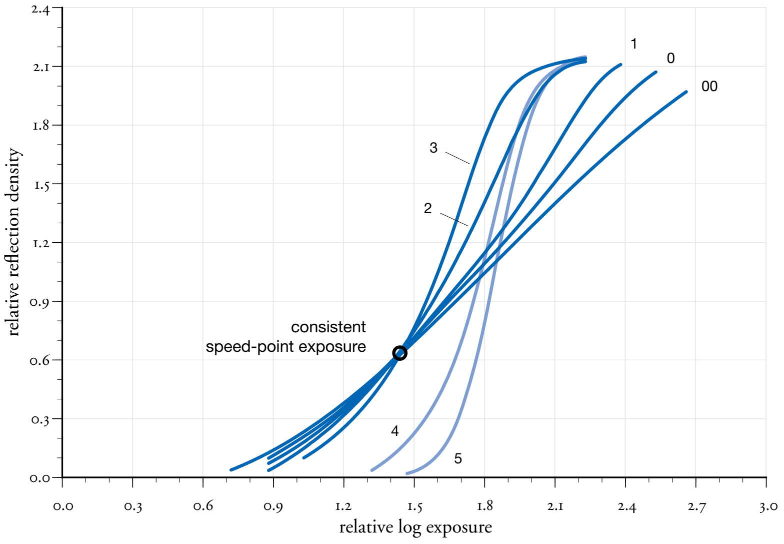
## The Value of Graphs

A graph is a wonderful thing. In fig.2, with just a few measurements and a smooth line, any print density can be calculated for a specified exposure or any exposure for a known density. Throughout this book the exposure and the relative reflection or transmission density is shown in logarithms. The higher the density is, the darker the print or negative is. Fig.2 also gives useful exposure information. By drawing a horizontal line at a given print density, the exposure difference between filter settings required to make this print tone can be determined from horizontal distance between the points at which each curve crosses the line. For instance in fig.2, the exposures for a constant midtone print reflection density of 0.6 (the ISO speed point) are approximately the same for filters 00-3 and about a stop more for filter-4 and 5 settings. Keep in mind that one stop of exposure is equivalent to 0.3 relative log exposure.

The slope of each curve gives yet more information. As the line of the curve becomes steeper so does the local contrast. Clearly every curve has a range of slopes, so this local contrast or separation is changing according to the overall print density. Notice how the slope of each curve becomes less near the highlight and shadow ends of the print scale. This accounts for the reduced tonal separation in the shadow or highlight areas of a print.

The nature of this tonal separation is extremely important to the richness of a print. Since at a given illumination, the human eye is about 5 times more sensitive to small variations in highlight print tones than shadows, highlight detail is especially critical. Under household lighting conditions, anything above a reflection density of about 1.9 appears to be black, but at the same time, the eye can distinguish

fig.2 These are the characteristic curves for Ilford's Multigrade IV RC paper printed with under-lens filters and a constant exposure time through each filter. The speed-point exposure is consistent, but shadow and highlight exposures differ significantly.



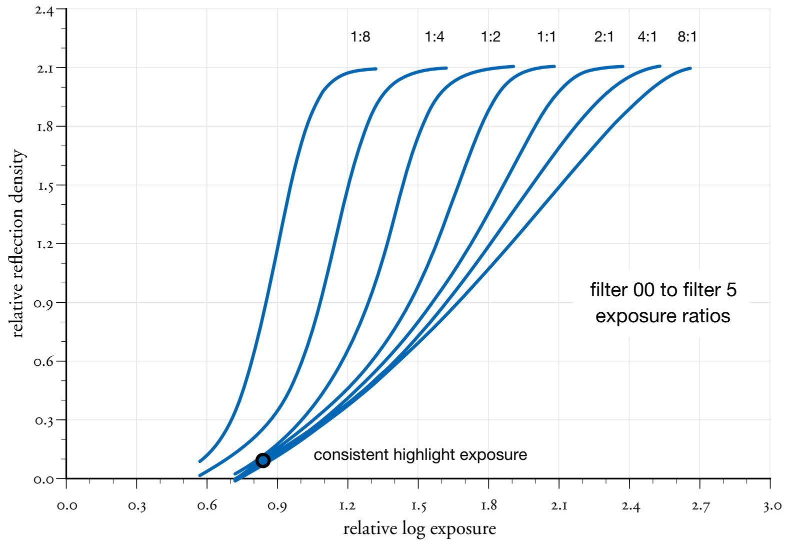


fig.3 These are the characteristic curves for Ilford's Multigrade IV RC paper, printed by combining fixed filter-00 exposures with halving ratios of filter-5 exposures. Note the difference in contrast, the consistency of highlight exposure and even spacing of shadow tones.

near white tones that a densitometer cannot separate. Under strong illumination, our ability to distinguish shadow detail improves and, at the same time, the intense reflection from the highlight areas actually decreases our ability to distinguish faint highlight details. For more detailed information on the subject of optimized print tones, see the chapter 'Fine-Tuning Print Exposure and Contrast'.

## Convention, Contrast Changes Exposure

Fig.2 shows the density/exposure characteristics of Ilford's Multigrade IV using their own under-lens filters. These are not 'ideal' curves but actual measurements under typical darkroom conditions. For these materials, the lower filter numbers 00-3 have the same exposure requirement (all the lines cross over) for a reflection density of 0.6, which corresponds to the ISO speed point for papers. The graph also shows that a different exposure is required for each contrast setting at highlight densities below 0.10, a crucial issue for a consistent highlight appearance. In practice this shows that once a highlight or shadow exposure has been determined for a given filter, any subsequent change in filter will require a new exposure test before the contrast change can be evaluated.

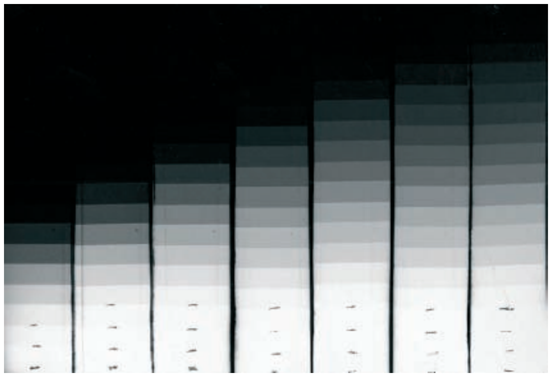


fig.4 This is a typical result of a split-grade exposures test.

The technique of split-grade printing can overcome this cerebral problem of juggling between exposure and contrast settings. It uses the idea that it is easier to find two exposures, one for highlights and one for shadows, than it is to go around in circles deciding on adjustments and corrections to print exposure and contrast settings. The second advantage, which is a by-product of the above, is one of fine contrast control. Since both exposures are within one's control, it is possible to print at any intermediary grade by one small exposure adjustment. However, to make split-grade printing viable, we need two things, a solid technique that does not require an exposure adjustment when the contrast setting is changed and easy to remember settings that allow repeatable results over a wide contrast range.

To determine the contrast/exposure relationship an Agfa step tablet was contact printed several times onto Ilford's Multigrade IV paper with different combinations of high-contrast (filter 5) and low-contrast (filter 00) exposures. Since most things in photography follow numbers that double each time, each subsequent contact print doubled the contribution of the high-contrast exposure. The transmission step tablet has nineteen 1/2-stop (0.15 density) increments and spans a density range of 2.6, enough to give a full tonal range on the lowest contrast setting. The print densities of each step for each combination of filter-00 and 5 exposures are shown in fig.3. This graph shows the print densities obtained with a 16-second exposure through filter 00 and additional 2, 4, 8, 16, 32, 64 and 128-second exposures through filter 5. So far, the results of similar tests with other VC papers have given very similar results. Another contact print using a different paper, in this case Agfa's Multicontrast Premium, is shown in fig.4.

## Split-Grade, Exposure Changes Contrast

The curves in fig.3 have three remarkable features. First, each curve has a different slope and, hence, effective print contrast, which if taken in isolation are very similar in shape to one of the curves in fig.2.

The second feature is that, unlike the curves with individual filters, the highlight exposure remains virtually unchanged for most of the lower contrast combinations and at worst requires about 1/2 stop (0.15 density) less exposure for the highest contrast setting. This can also be seen visually by examining the highlight end of the contact prints in fig.4, where all but the two high-contrast strips have a similar highlight appearance.

The third feature is the remarkably even spacing of the curves at a typical print shadow tone (around 1.9 reflection density). This can be clearly seen on the contact print, fig.4. Here the position of the same typical shadow tone moves one step on the next strip. Practically, if we continually change the ratio of the two exposures by two, we can produce sensible and even increases in print contrast. To show this, the effective paper exposure range (R) for each exposure combination is shown in fig.5. The vertical axis represents the paper exposure range and the horizontal axis shows the hard versus soft filter exposure ratio. This graph was calculated from the curves in fig.3 by noting the difference in exposure between a relative print reflection density of 0.04 and 1.84. To calculate the exposure range (R), each log exposure difference was multiplied by 100. In this figure, the contrast variation simply changes linearly with the ratio of the two exposures measured in stops. This figure now allows the photographer to find the ratio of the filter-5 and 00 exposures to reproduce any contrast setting. If your enlarger timer has an f/stop mode, then clearly the two times can be conveniently set up with a few button presses between the two exposures. When a low or normal print contrast is expected, the exposure is most accurately judged with a test for the highlights using filter 00, followed by a test for the shadows using filter 5 to set the overall print contrast.

Another look at fig.3 shows that for the two highest contrast settings, the required highlight exposure decreases by about 1/2 stop (0.15 density), simply because the massive filter-5 exposure is starting to influence the highlight appearance. Since for this high-contrast condition most of the overall exposure is with filter 5, it makes sense to try the experiment in reverse, keeping the filter-5 exposure constant and varying the filter-00 exposure. Measured in the same way, the result is shown in fig.6. As expected, the shadow exposure for the two highest contrast settings is very similar and the addition of a small amount of filter-00 exposure on top of a filter-5 exposure has no appreciable effect on shadow rendition. This is doubly true, since our ability to distinguish shadow information is less than that at the white end. The added benefit of this exposure order is that soft exposures are easy to burn in selectively without leaving telltale haloes on the print. As before, the lines on the graph fan out evenly, indicating regular grade spacing. Indeed as you might expect, the contrast/exposure graph is identical to that in fig.6, dispelling the myth that the order of exposures makes a visible difference. Thus, with expected high-contrast settings it is more accurate to work out the exposure for the shadows with the number-5 filter and then burn in the highlights with filter 00 for the right contrast effect. In theory, the curves in fig.3 and fig.6 show that it is possible

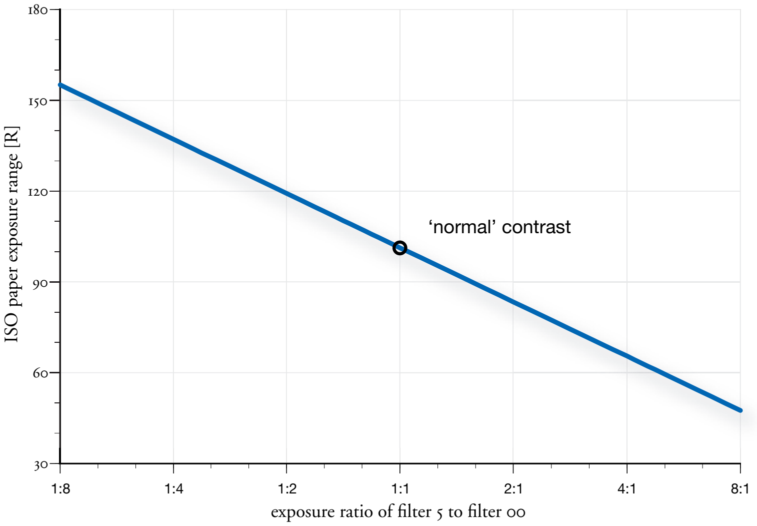


fig.5 The paper exposure range (contrast) depends on the exposure ratio of filter 5 to filter 00. Note that an equal exposure time through each gives a 'normal' paper contrast.

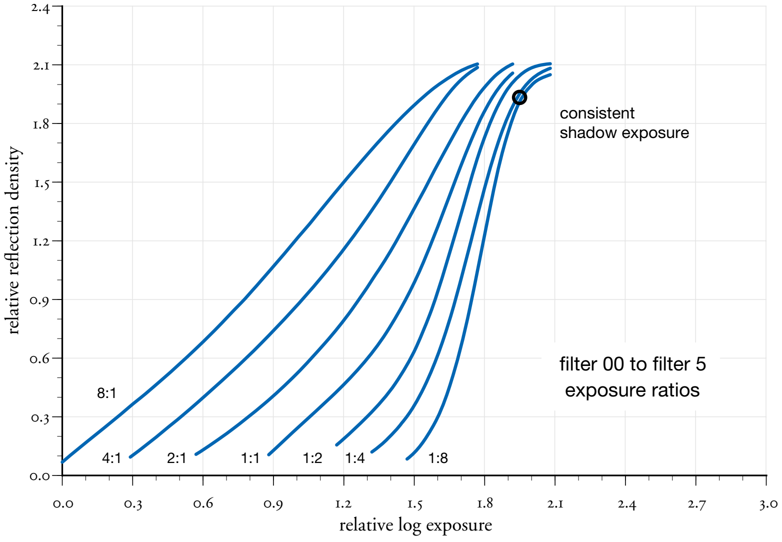


fig.6 Keeping filter-5 exposures fixed and varying filter-00 exposures have no appreciable effect on shadow rendition.

to start with a single highlight-based exposure, using filter 00 for all medium to soft contrast settings. For improved exposure consistency with hard to very hard contrast settings, a shadow-based exposure starting point is preferred using filter 5. Using conventional terms, in the first case, we are using filter 5 to burn in the shadows on top of a filter-00 exposure, and in the second case, we are using filter 00 to burn in the highlights of a filter-5 exposure. The contrast graph in fig.5, derived from either fig.3 or fig.6, clearly shows that if the soft versus hard exposure ratio is varied in stops, or fractions of a stop, there is a constant contrast change.

In addition, by some curious stroke of luck, each doubling or halving in the ratio of the two exposures yields a paper contrast almost exactly equivalent to the next full paper grade! Therefore, the horizontal axis of fig.6 could read 8:1 = filter 00, 4:1 = filter 0, 2:1 = filter 1 and so on. Hence, an f/stop timer with a resolution of 1/12th stop will be able to control contrast to 1/12th of a grade with the minimum of fuss!

## Practical Considerations

To demonstrate this technique, a bold portrait with plenty of highlight and shadow detail was chosen. This unusual portrait was deliberately lit to create drama and a bold effect, without losing the delicacy of the hair and skin.

In this case, I decided to determine the highlight exposure with filter 00 and then calculate the additional filter-5 exposure to make the shadows just right. To find the highlight exposure, I made four test

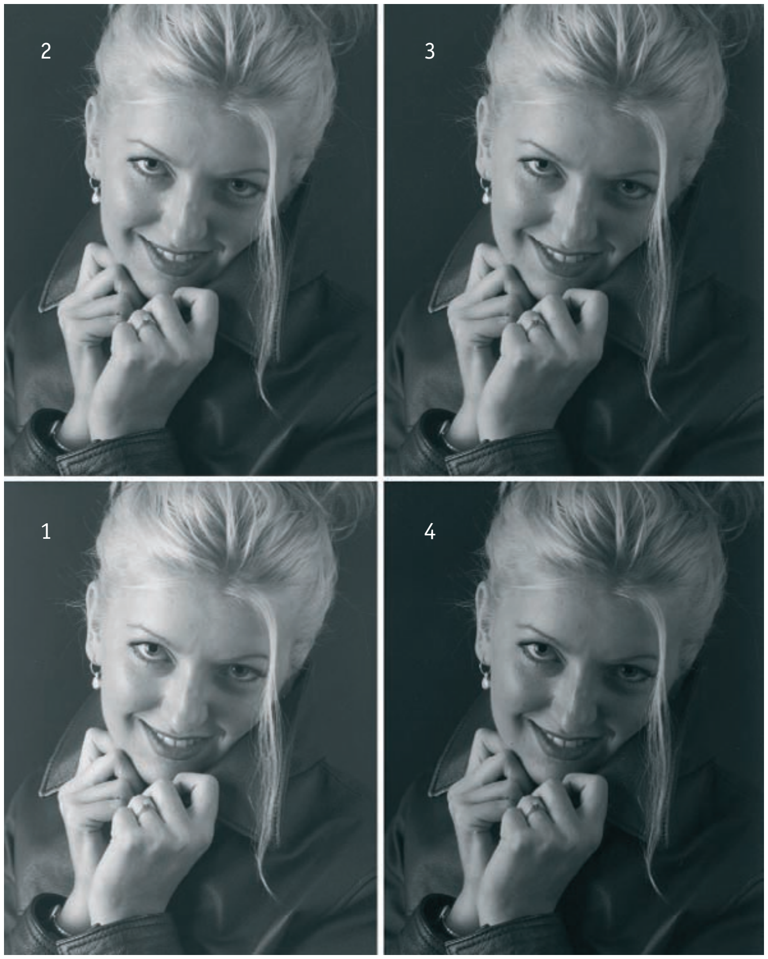


fig.7 (below left) Increasing filter-00 exposures, starting at 5 seconds increasing in 1/4-stop increments.

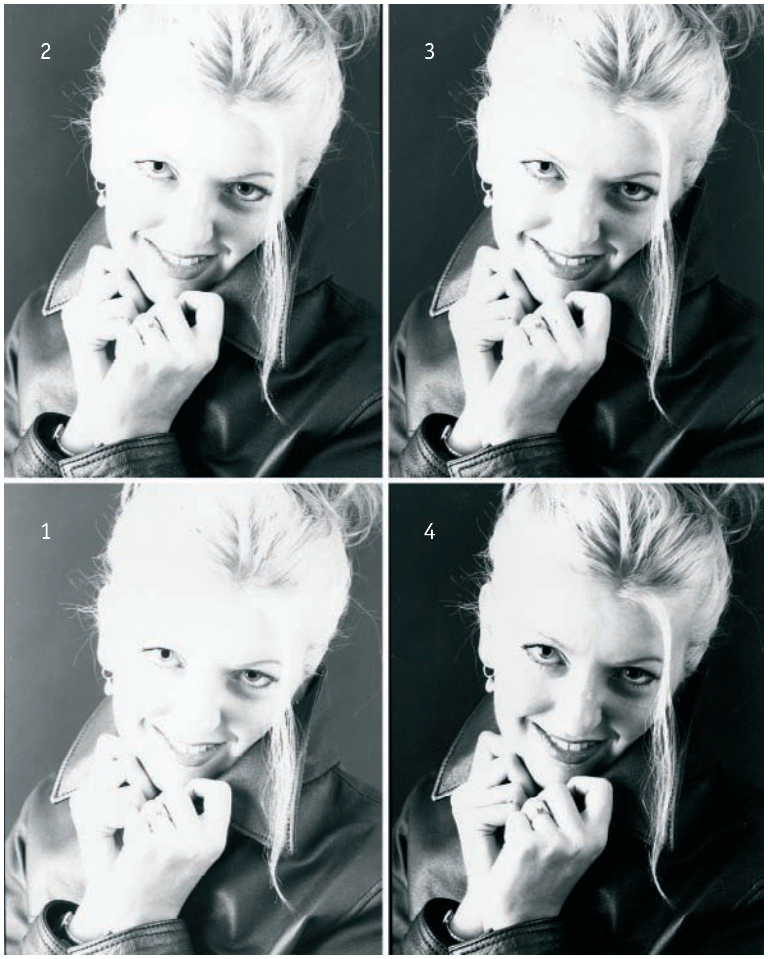


fig.8 (below right) Increasing filter-5 exposures, starting at 5 seconds increasing in 1/4-stop increments.

prints in 1/4-stop increments (fig.7) on an 8x10-inch sheet of Agfa's Multicontrast Premium paper. These test prints were made with a 105mm enlarger lens and a 35mm negative to keep the enlarger head at a comfortable height. After developing and drying the test print, I judged the second print to have just too much exposure to register the highlight tones with its 6-second exposure. A point of note, 'just enough' is the best adjective to describe the highlight exposure. It is better to choose on the light side rather than the dark, since any additional filter-5 exposure will always add some highlight tone. With coarse exposure test prints, which bridge the desired results, it may be appropriate to repeat the test with finer settings.

The second set of test prints (fig.8) shows the effect of increasing exposure with filter 5 and the third the overall effect when these are added to the chosen filter-00 exposure (fig.9). Each frame has 1/4 stop more filter-5 exposure than the previous; therefore, in fig.9 each frame is about a quarter grade different from its neighbor. Notice how the appearance of the shadows in fig.8 and fig.9 are almost identical and how the highlight appearance of the blonde hair in each of the test prints in fig.8 remains virtually unchanged by the increasing hard exposure.

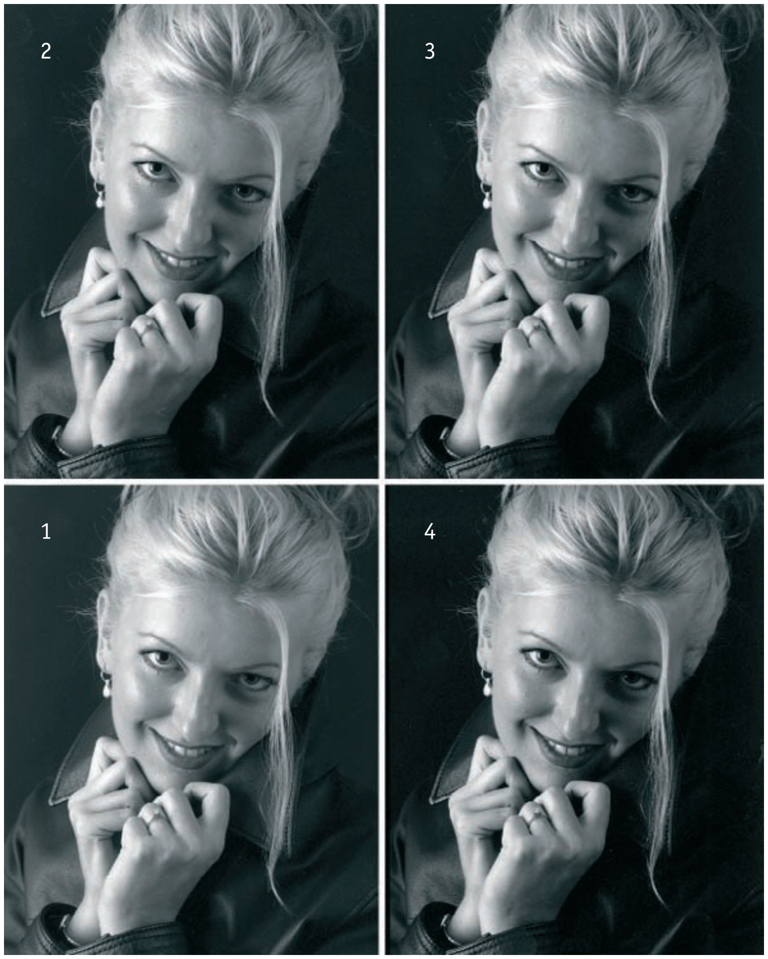
In this case, a print exposure somewhere between frames 3 and 4 at around 8 seconds would just give a visual hint of the jacket and nothing more. The final straight print (fig.1) was made with a 5.3-second (filter 00) and an 8-second (filter 5) exposure, scaled to the new enlargement size.

Clearly, the balance of the picture can be improved, but it demonstrates the basic technique. For instance, some darkening of the hands and some lightening of the jacket on the right would help balance the picture, as would some careful burning down of the highlight on the cuffs and the corner of the collar.

Some quite distinguished photographers have made claims that the print quality obtainable with this technique is unique and cannot be accomplished with a single exposure system. In retrospect, this erroneous statement is probably based on human enthusiasm and the fact that the prints compared were not of exactly the same effective contrast or exposure. So far, there has been no evidence that demonstrates a difference between a split-grade exposure and a single-exposure print at the same ISO print contrast. If this is the case, what then are its advantages?

Recall what we have just done. We have determined the exposure and contrast setting of a print with just two test strips. At no time did we discuss the contrast of the print, merely the appearance of the shadow and highlight regions. For many, this avoidance of the contrast versus exposure cycle is reason enough to adopt split-grade printing. For others, it is the start of something altogether more powerful, which will be discussed in the next chapter, where we will use some more examples to show how split-grade printing creates unique opportunities for dodging and burning.

fig.9 Combined filter-00 exposure with increasing filter-5 exposure. Notice how the brightest highlights remain unchanged while the shadow areas become progressively darker.



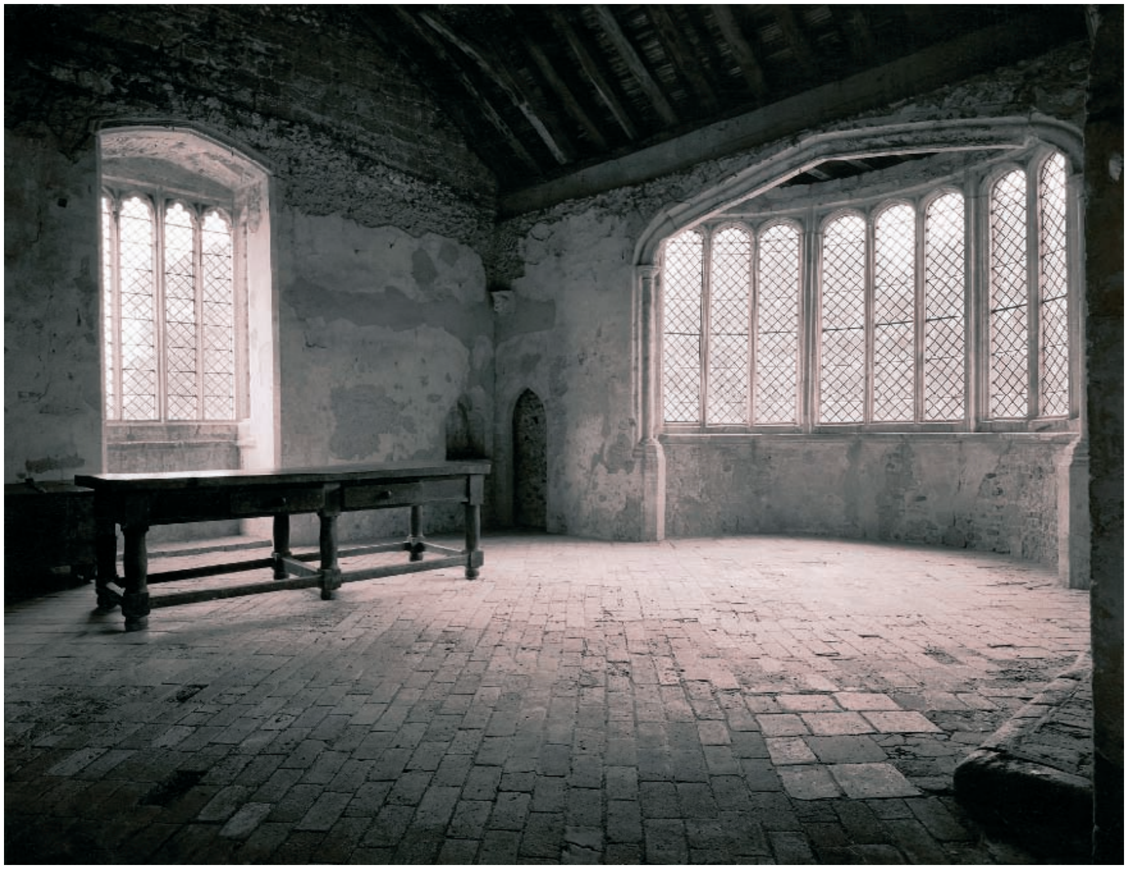
# Advanced Split-Grade Printing

## Selective contrast control with VC papers

In the previous chapter, a straight print was made by combining two exposures, which were made through the extreme contrast filters. An identical print can be made with a single exposure using the magenta and yellow filtration of a color enlarger head. Split-Grade printing, however, is more than just another alternative to simple contrast control. Unlocking its full potential offers more creative opportunities for local control of contrast and tonality than any other darkroom printing technique. This assertion is worded carefully, since one requires the twin objectives of the degree of control and the ease with which it can be applied. For me, the realization of this was a revelation in a decade of printing. This chapter will show how sophisticated split-grade printing provides full contrast control, and it may change your printing habits too.

In this chapter, we avoid the use of graphs, for it is the practical application that is being investigated. Having created a work print, we consider what manipulations during and after the two exposures can bring expression to an otherwise literal interpretation.

fig.1 This is the final print of Castle Acre priory in Norfolk, England.



### Additive Exposure

Here is every darkroom worker's dilemma: Once you expose paper to light, you cannot remove its effect. Consequently, to enhance an existing latent image, one can only add light to it. It is impossible to increase local tonal separation in, for example, a shadow area that is already dense and dull, or alternatively add a sparkle to highlights already with sufficient print tone, without reaching for the bleach bottle.

Conversely, it is easy to dull down borders or distracting highlights with a selective soft burn-in or flash exposure. This exposure will affect the pale tones without adding much density to the midtones and even less to the shadows. To get significant separation in any tone, one has to use the highest contrast available, normally filter 5. Using a filter-5

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50042-9

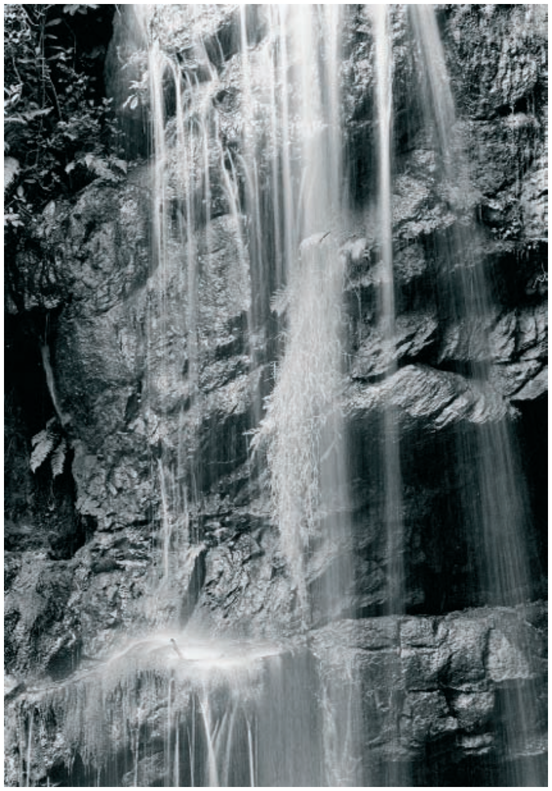


fig.2 (far left) This print of the Kilfane waterfall in Ireland was made with two basic split-grade exposures.

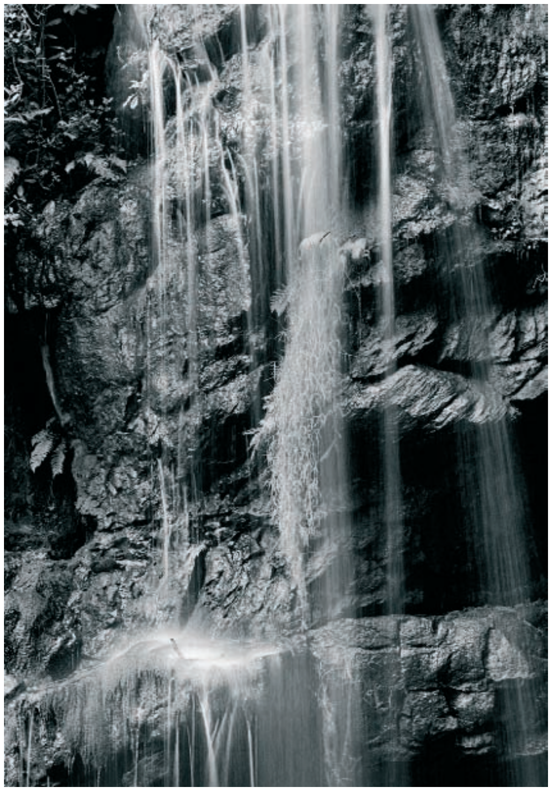


fig.3 (left) This is the same split-grade print but with added filter-5 exposure in the central wet rock face and a filter-00 edge burn.

setting to print in large areas of a normal contrast negative is not the sort of thing that comes naturally to mind. In practice, the fears of leaving telltale marks can be overcome with a few simple precautions.

## Kilfane Waterfall

The simple example in fig.2 and 3 shows how a basic split-grade print can be enhanced by painting in shadow and midtone detail with filter 5. Fig.2 is a straight print of the Kilfane waterfall in Ireland from a 35mm XP2 negative, developed under normal C41 conditions. The combination of weak lighting and the characteristic low-contrast negative requires a hard setting for the basic print.

Here the customary two test strips indicated a combination of an 8-second exposure with filter 00 and 35 seconds with filter 5, approximately equivalent to a single filter-4 exposure. This combination was chosen to give a hint of detail in the highlights and good depth to the deepest shadow. Obviously, more traditional methods could have been used to make an equivalent print. Fig.2 has an overall contrast and exposure setting to capture the information on the negative and map it to the tonal range of the printing paper. Note how the central portion of this straight print lacks conviction and the highlights are weak on the wet rock and splashing water.

In fig.3, a burn-in exposure through filter 5 was added to add depth and bite to the wet rocks as well as enhance the details in the water and weed. The extra 1/2-stop exposure was checked with a test strip. A foot switch attached to the enlarger timer allowed both hands to mask the right and left hand sides of the print during the exposure.

Note how the hard exposure adds tone to the blacks and midtones without darkening the critical highlights. Apart from the weak central details, the highlights near the top and sides of the print also draw the eye from the main image. To suppress these distracting details a soft exposure was added to darken the light print tones without blocking the shadows. Four separate graduated exposures were made with filter 00, fanning a piece of wavy card, to progressively mask off each edge of the print.

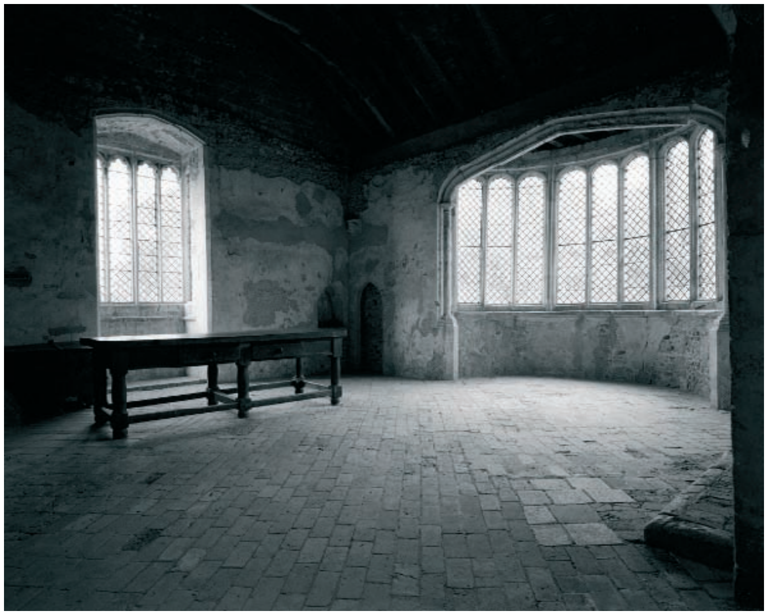


fig.4 The straight print of Castle Acre priory leaves us with a dark roof structure, which lacks the necessary detail and hides the wooden rafters in deep shadow.

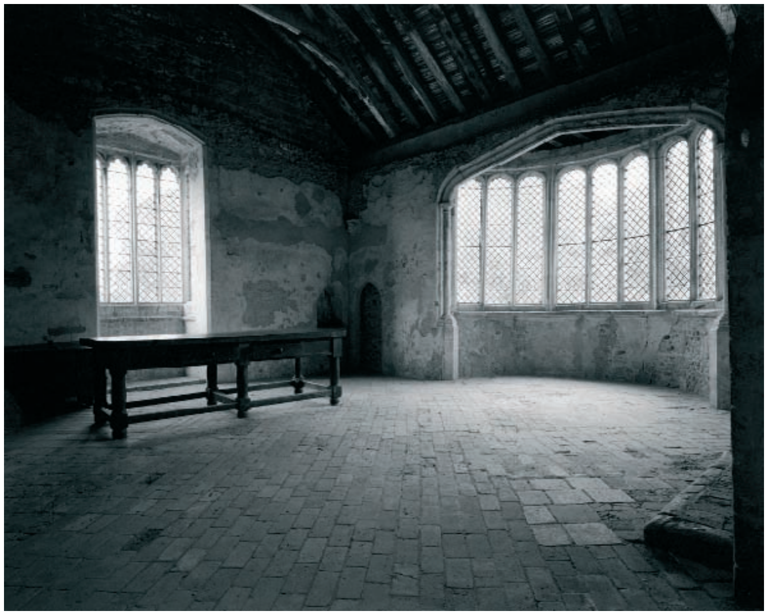


fig.5 For the improved print, the rafters were dodged during the soft exposure, increasing shadow detail and adding substance to the roof structure.

This waterfall print is a simple example of using an additional local hard exposure to add depth to weak shadows, as well as details to light tones. However, another unique and powerful feature of split-grade printing, one that is not available with additive multiple-grade exposures techniques on variable-contrast paper, was not considered for this print.

## Further Controls

The easiest way to objectively describe this unique and powerful feature of split-grade printing is to consider the following:

During the main exposure, there are two, not one, opportunities to dodge key areas of the print at different filter settings. This ability to selectively hold back soft and hard exposures gives almost total local contrast control. This level of control is very difficult if not impossible to achieve on a conventional print with add-on exposures, unless you build up a print like a jigsaw puzzle.

Clearly, not all prints require this degree of manipulation, but it is surprising how often it is used once we have this opportunity in our armory. The next step is to evaluate another working print, which needs rather more manipulation. Fig.4 is a straight print of an XP2 negative, taken in the Castle Acre priory in Norfolk, England. In this print, there are several select areas of concern. To make the following evaluation easier to follow, it makes sense to consider the shadow, midtone and highlight areas in turn.

## Enhancing Shadows

When we take a photograph and reproduce it literally, we immediately notice how dense and impenetrable the shadows are, compared with our visual recollection of the scene. This is the difference between the flexibility of our eyes and brain, and the limitations of photographic material properties. To some extent we can overcome this problem by printing our shadows at a higher effective contrast, either by lowering the overall density of the shadows from the shoulder of the paper characteristic, printing it at higher effective grade setting or both.

In the first case, we run the risk of losing the maximum black, and in the second, we may be left with stark highlight details. I recommend to approach contrast increases carefully and not to overdo the effect. Talking about shadows, we assume that the majority of the print tones are dark with only small patches of light. If these patches become too large or dominant, the overall effect will be coarse and clumsy.

The straight print of Castle Acre (fig.4) was made with a 14-second exposure through filter 00, overlaid by 10 seconds through filter 5 and judged to give good gradation in the midtones. As a result, the shadowy area of the rafters lacks detail. As the print is made with a combination of 'hard' and 'soft' exposures, we know that the hard exposure puts in the shadow detail and the soft fills in the empty highlights.

Putting the main advantage of split-grade printing to use, in fig.5, the 'soft' exposure is held back in the area of the rafters for most of its exposure time. The effect is to increase contrast and add substance to the roof structure by lifting the lighter tones in that area without upsetting the deep shadow tones.

The effective grade of the rafters is now equivalent to a filter-4 exposure. The rest of the print is still comparable to a filter-2 setting. Typically, print exposure manipulation with soft contrast settings is rather tolerant of poor technique. For the improved print in fig.5, no exact masks were used, but the mask was moved a little to avoid telltale signs otherwise left by the technique.

Later on, the new detail, created at the extreme edges of the print, can be toned down with an additional classic soft-grade edge-burn to prevent the rafter lines from leading the eye out of the picture.

## Creating Midtone Definition

For many, midtone contrast is the key to a picture. If you consider the human face, most of the tones are midtones, with just a few nuances of tonal extremes to add interest. We hear various adjectives like 'muddy' midtones or 'lacking separation' to describe lackluster prints. If we consider fig.4 again, the flagstone floor in the foreground is rather lacking in crisp detail. With the right emphasis, the cracks of the flagstone will lead the eye into the picture.

If we take a look at the floor, the basic exposure has already given essential tonality to the flagstones. If we want to add more detail, we only need to lighten the floor during the basic print exposure to avoid these tones from getting too dark. In this case, since we wish to make the cracks appear darker than they are in fig.4, yet keep the tones of the stones the same, we lightly dodge the stones during the main soft exposure through filter 00, and then, we subsequently add the detail with additional exposure with a filter-5 setting to the floor. Since this additional hard exposure has more effect on dark tones than light, it enhances the tonal separation of the flagstones, but only adds the slightest additional tone to the stones themselves.

The final print is shown in fig.1. In this print, I divided the soft exposure into two, alternatively shading the roof and floor with my hands. The rafters were a little overdone before, but it made the point. Then, another 4 seconds (1/2 stop) through filter 5 was added to the flagstones. I used a penny-sized hole in a piece of card as a mask to burn in the area just under the window. Even here, with a high-contrast filter burn-in exposure, no obvious edges can be seen, since the tones most affected by the hard exposure are the cracks and texture of the flagstones. Just to make sure, the card was kept in constant motion, effectively fading the burn-in effect towards the edges of the floor.

## Adding Highlight Detail

Last but not least, we consider the lightest areas of the print. In fig.5, the flare behind the windows is just attacking the subtle tree shadows. In fig.1, the glazing bars have better density and detail, put in with some simple burning. In both cases, we require more substance to the precious highlights and to the glazing bars. This is accomplished with either a small additional exposure with filter 2, or if you prefer, two equal exposures through filter 00 and 5. Traditionally, one might just have used a soft exposure to burn in the highlights, but by using a hard setting, it is possible to pep up the glazing bars and add detail to the window frame at the same time.

Each window received an additional 1/4-stop exposure through filter 00, extending to the window surrounds and a similar amount of exposure, with filter 5 through a penny sized hole in a piece of card, to the flared area. In each case, the masking was crude, but by avoiding straight edged masks and by keeping the mask on the move, no telltale marks can be detected in the final print.

The second dodging opportunity mentioned earlier, namely dodging during the hard exposure, preferentially lightens darker tones and reduces tonal separation in light areas. Clearly, it is also a useful tool to equalize the shadow densities in a print. Sometimes it is easier to dodge and burn using simple masks, rather than making a complex mask for one operation. With a complex mask, the ability to move it about during the exposure is restricted, and it increases the chance of telltale boundaries.

A good example of this can be seen in the bottom right corner of fig.1. Here, during the main filter-5 exposure, this small dark area was lightly dodged to lighten the shadow density. Later, when burning down the flagstone shadow detail, I could stray across the corner of the fireplace without creating an annoying empty black blob on the print. Selective dodging during the filter-5 exposure could also have been used to lighten some areas of the priory walls without creating obvious, distracting highlights.

## Practical Considerations

The continual swapping of grades and exposure times can be tiring after a while. An under-lens filter kit and a dual-channel timer can ease the situation. In themselves, they do not alter the quality of the final result but go some way to improve the darkroom experience. Some of the programmable models will even remember the separate sequences of exposures for each of the filters. This can be especially convenient when a limited print run is made.

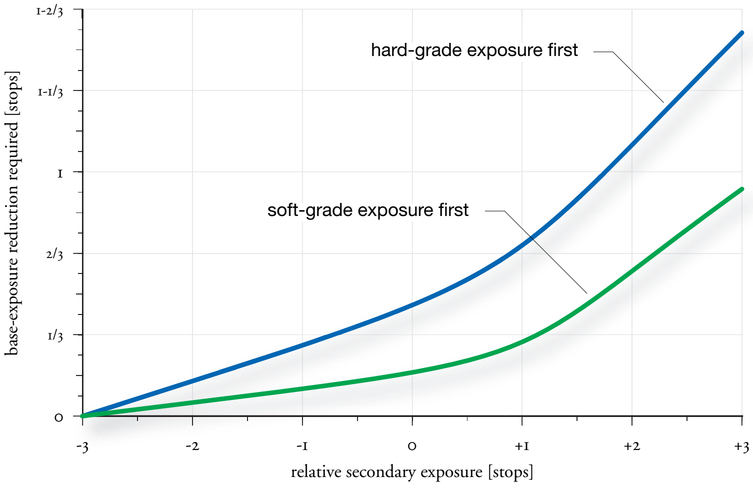
The data for the paper curves in figures 3 and 6 of the previous chapter 'Basic Split-Grade Printing' was rearranged to produce a practical base-exposure correction graph for split-grade printing (fig.6). In practice, one makes a test strip at either a soft-grade setting (for medium to high contrast negatives) to determine the correct highlight exposure, or at a hard-grade setting (for medium to low contrast negatives) to determine the correct shadow exposure. In either case, the test result is the base-exposure. The second exposure, at the opposite contrast setting, burns in the missing image tones. However, a small reduction in base-exposure is always required to compensate for the secondary exposure contribution, which was missing in the test strip. This base-exposure reduction can be read from the graph in fig.6. For example, one makes a test strip at a soft-grade setting and selects the best highlight exposure. A second test strip is made with different high-contrast exposures, which is added to the predetermined soft-grade exposure. The correct secondary high-contrast exposure is judged from the shadow appearance. Now, the soft-grade base-exposure reduction is read from the graph, against the relative second exposure setting. Alternatively, one might start with the high-contrast test strip and then use the graph to determine a reduction in the high-contrast exposure to offset the effect of the added soft-grade exposure.

Note that f/stop timing is not obligatory, but as described in the chapter called 'Timing Print Exposures', it is very useful for judging test prints and keeping a constant ratio of the main exposures and burn-in exposures, especially if the proof is at one size and the print is at another. A single test strip can determine the effective exposure increase for the new enlarger height, and the previously derived printing map, showing the extra exposures in stops, is still valid.

With split-grade printing, since the basic print is made with two separate exposures, the darkroom worker has the opportunity to raise or lower the contrast in specific areas of the print by selectively masking the print during the hard and soft contrast exposures. Having made these two exposures, subsequent burning down with the extreme soft and hard grades allows further control over local contrast with, in many cases, easier masking conditions.

Split-Grade printing, like many other printing techniques, is a sophisticated technique to be used selectively when the situation calls for it. For some, the abolition of contrast settings is a liberating experience, but even then, not all prints require the full versatility that Split-Grade printing can offer. With the almost universal adoption of VC papers, many photographers use this technique without even realizing it.

fig.6 This material-dependent graph shows the amount of exposure reduction required to the first exposure, depending on the relative exposure of the opposite grade. For example, if the soft-grade base exposure requires 10 s and the subsequent hard-grade exposure requires 20 s (+1 stop), the base exposure must be reduced by 3/16 stop to reproduce the predetermined highlight density. Conversely, if the base exposure requires 10 s with filter 5, followed by a 20s exposure with filter 0, the required reduction in base exposure is roughly 2/3 stop to maintain the desired shadow density.



# Print Flashing

## Dim light in the gloom

In addition to the main image-forming exposure, film and paper can be given a brief non-image forming exposure to control excessive contrast. The effects on film and paper are quite different, and the earlier chapter 'Pre-Exposure' has already examined the effects on film in detail. In this chapter, we will explore the application of non-image exposures on photographic paper, which, unlike split-grade printing, can be used with fixed-grade or variable-contrast papers.

There are two types of non-image exposure, flashing and fogging. Flashing exposes a print to small amounts of uniform non-image forming light, below the paper's threshold and insufficient to produce a tone by itself. But when added to the image exposure, flashing changes the appearance of the print. Larger amounts of non-image forming light can produce an actual gray tone by itself, and this is referred to as 'fogging'. Since fogging is hard to control and can easily lead to 'dirty' highlights, we will concentrate on flashing alone.

The circumspect definition above is quite deliberate, since flashing is used in many different ways and for several effects. For instance, it can be applied before or after the main exposure. It can be applied to the whole print, or just a select part to improve highlight or shadow detail. What it does is change the distribution of image tones (gradation), in effect, modifying the paper's apparent characteristic. Flashing, like all other photographic techniques, is a tool to be used selectively and when the need arises. Some printers use it more frequently than others do, and some may never use it at all, preferring to use a low-grade burn-in instead.

### Flashing Fixed-Grade Papers

Stocking several boxes of fixed-grade papers can turn into an expensive initial investment, or worse yet, with some emulsions, there are only one or two grades available. For these papers a range of techniques have to be used, to push and pull and generally modify the print tonal characteristics, to achieve the desired pictorial effect. Water-bathing, split development, pre-bleaching, post-bleaching, toning and surface treatments are on the list of techniques, to name but a few.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50043-0

One reason for all this manipulation is that many of us still use roll film and do not have the nature or desire to tailor individual film development to individual paper characteristics. The other is that most scenes do not translate into desirable print tones without some coercion. After all, film exposure and development can only determine two points on the tone distribution curve.

Even with special developers that alter the highlight and shadow roll-off, one is not entirely in control. These have a non-reversible effect, and the final print can still be way off in tonal balance. If you use a considerable number of emulsions, to fully understand all the combinations would be a crusade that would put pictorial considerations aside for many years.

As with poor safelights, enlarger or darkroom light leaks, flashing will reduce the overall print contrast. Pictorially, this only occurs for the highlight to midtone range of print tones. In common with the other investigations of printing techniques, we contact print a graduated step tablet and plot the density results on a graph. However, this time we will remove the step tablet after the contact exposure and make an additional flash exposure to the paper.

Fig.1 shows the tonal effect of flashing on a normal-grade test print. For you to be able to repeat these results, the exposure notation on the graphs refers to the flash exposure in stops relative to that required to produce threshold white. Consequently, 'filter 2, -2.5(2)' refers to a print created with a filter-2 base exposure and an additional flash exposure of 2.5 stops less than that required for threshold white. The number in brackets refers to the contrast setting of the flash exposure, thus (2) indicates that a filter 2 was also used for the flash exposure. If you have a baseboard lightmeter zeroed to the highlight exposure, such as the ZoneMaster or Analyser, it is quite easy to set up. The word 'filter' is exchanged for the word 'grade' in case that graded papers rather than VC papers have been used.

In fig.1, we see that as the flash exposure increases, the print density slowly builds up in the areas where the palest tones are. The additional print density makes the highlight have lower local contrast. This can be read from fig.1, since the slope becomes progressively less steep as the amount of flashing increases. Conversely, at the shadow end, very little to no difference in print appearance is seen.

In the previous example, the overall exposure range of the paper is increased by about 2 stops before fogging occurs. The fog threshold is the point at which the flash exposure is sufficient to register a print tone without any further exposure.

The results shown in fig.1 show that it is possible, within limits, to fit a high-contrast negative onto a normal grade paper. One could expose the image for the shadow rendition and then burn in the highlights with the flash exposure, in much the same way as split-grade exposures. Pictorially, this is demonstrated by the normal-grade print in fig.2 (no flash) and fig.3 (flashed print). The image exposure in fig.3 was adjusted so that the accent black (without flashing) is the same print tone as in fig.2. The flash exposure is then used to fill in the highlights. Note how the shadow detail has only been altered slightly, but the highlight detail in the waterfall has become visible. The effect is not perfect, but as will be shown later, it is the first step to making a sparkling cascade.

There is another subtle way of using this effect. If we wanted a higher tonal separation in the shadows, we could print a normal negative with the shadow contrast of a filter-3 setting and the highlight contrast of a filter-1 setting. This would visibly open up the shadows and yet have an overall normal contrast. We shall leave the resulting images to the imagination. The resulting tonal changes are plotted in fig.4.

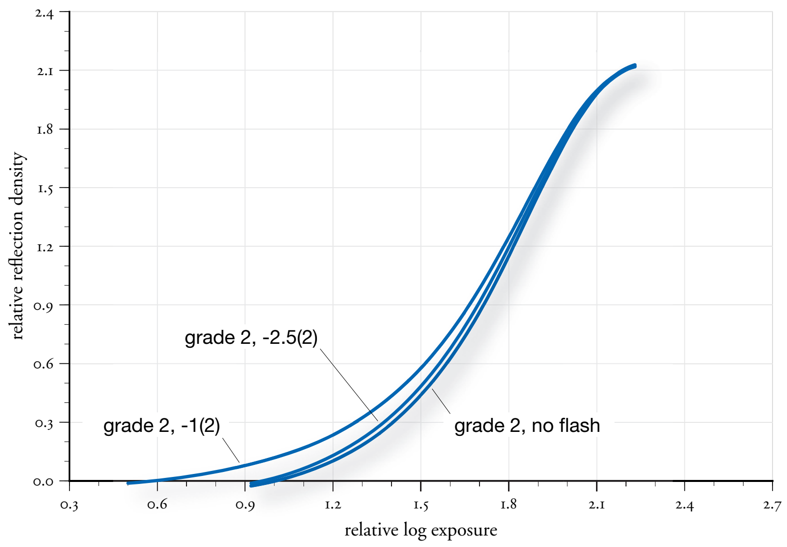


fig.1 These are the characteristic curves of a fixed-grade paper with and without an additional flash exposure. The flash exposure time is 1 stop less than what would be required to reach threshold white with grade 2. The highlight and midtone gradation is significantly altered by the flash exposure, but shadow gradation is not affected.

In fig.4, we have two curves. One is a low paper contrast (filter 1) and the other is a high paper contrast (filter 3) with the right amount of flashing given to it in order to have the same overall effective exposure range. The correct amount of flashing was determined by using a test strip with increasingly higher flash exposures. The curve of the flashed hard paper is steeper in the shadow area (high print density) than the normal contrast paper. Shadows will exhibit more obvious texture definition with this combination.

This agrees with the conclusions in the chapter on pre-exposure from Phil Davis' book *Beyond the Zone System*, where a flash exposure is used to tame a high-contrast negative with a normal contrast paper. The flash exposure reduces the overall contrast of the print and allows a small reduction in the main exposure. This combination gives a highlight appearance similar to using only filter 1 and a shadow appearance similar to that of using filter 2. Note that this more abrupt change in curve shape at the highlight end of things is the principal reason for the pictorial difference between split-grade printing and flashing. Indeed, some papers, notably Kodak Polymax, have almost identical highlight appearance up to the midtones for all grades but the extremes. Nearly all the contrast changes occur within the dark midtones and blacks. For this reason, the unfortunately no-longer manufactured, Kodak Polymax was a very good candidate for flashing, because flashing was the only mechanism to alter its highlight appearance.

## Flashing Variable-Contrast Papers

Each of the flashing effects discussed so far apply to fixed-grade papers and VC papers in the same way, with one important exception. The contrast setting of the flashing exposure is critical. Flashing a print with hard or soft filtration during the flash exposure gives surprising results. In retrospect, these results are not unusual, since they are in keeping with what is known about the behavior of variable-contrast papers at different contrast settings.

In the context of the flashing exposure a 'hard' flash is one with filter 5 in the light path, or full magenta filtration. A 'soft' flash would be using a 00 filter or a high degree of yellow filtration. In my own darkroom, I leave the negative in the enlarger and insert a diffuser on top of the selected contrast filter, sitting in the under-lens filter holder.

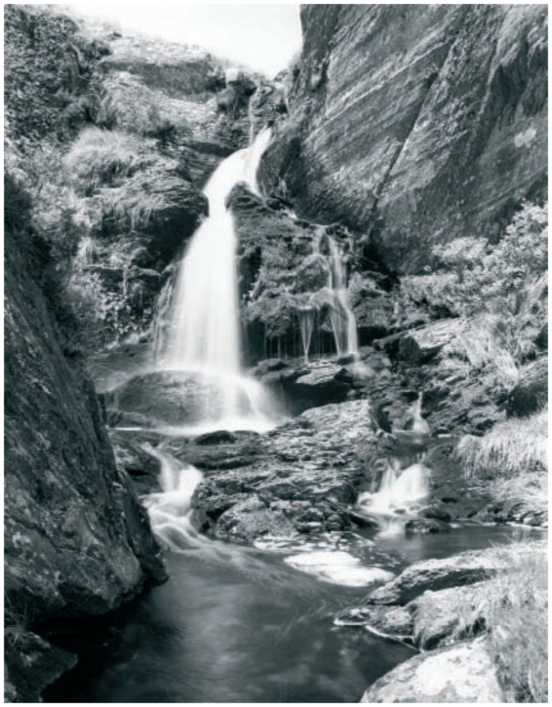


fig.2 (far left) straight print, no flash

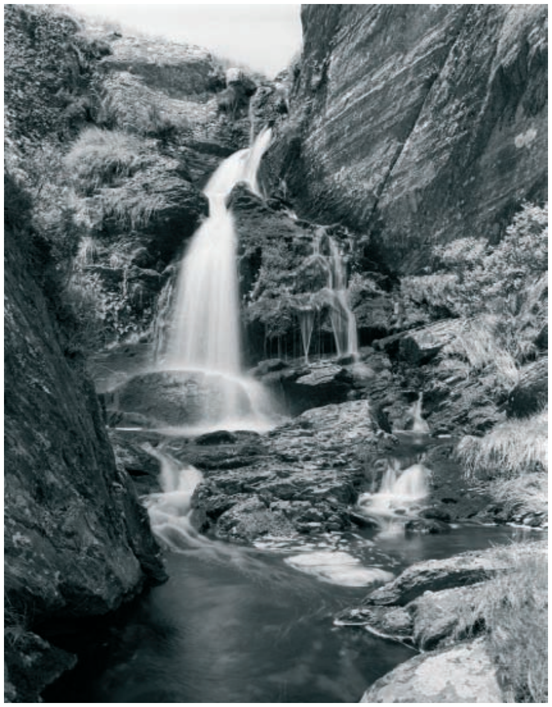
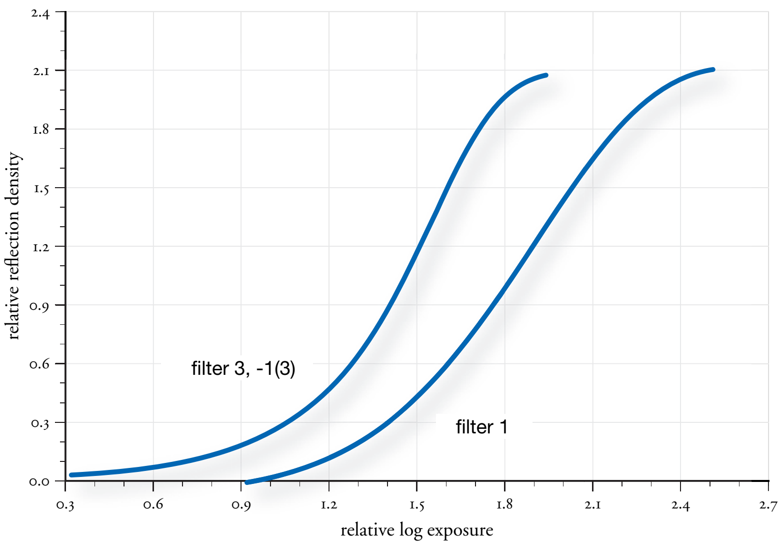


fig.3 (left) straight print, with flash

If the flash exposure is made with a heavily diffused underexposed version of the image exposure, at the same filter setting as the main print exposure, then similar results to flashing on a fixed-grade paper should result. If, however, the filter of the flashing light is changed, some rather surprising things happen. In fig.5, the effect of flashing a filter-2 print with hard and soft filters of flashing light are plotted. It can be seen that a high-contrast flash exposure gives a uniform increase in print density. If you compare the filter-2 curve with the one that reads 'filter 2, -2(5)', the entire curve is shifted along the exposure axis. That is, the flash exposure not only darkens the highlights, but also adds extra print tone right up to the deepest shadow tones, causing them to block up. In this extreme case, the effect is the same as simply increasing the image exposure.

By contrast, using the softest filter in the light path during the flash exposure (see fig.6) results in a classical highlight-only affected print. It is a little tricky to visualize the effect from the graphs, but by using a soft (rich in green light) flashing light, only the extreme highlights are affected. The intermediate, done-at-the-same-filter exposure produces identical results on the fixed-grade paper. This offers greater control and can be very useful. By using a very soft flash exposure, again only the extreme highlights are affected, which gives a more subtle effect than that described in the previous section on fixed-grade papers. For instance, we can print an image with filter 4 and flash it with filter 0 to further improve shadow definition. An example is shown in fig.7c.

fig.4 Here a contrast filter-3 print with additional flash exposure is compared to a filter-1 print. Note how the overall contrast (exposure range) is almost the same, but the flashed print has a highlight gradation similar to filter 1, while providing higher shadow contrast.



In practice, fig.7a-d show the effect of no-flash, normal flash, soft flash and hard flash on a normal contrast subject. In each case, the main image exposure has been left unchanged, so the effect of the flash exposure (-1 stop setting) across the tonal range can be seen. As we know, subtle changes in prints are not always discernible in publication, but you should be able to see how the midtones and shadow tones are affected least in the soft flash and progressively more as the contrast setting of the flash exposure is increased. Therefore, it can be sensed that larger amounts of 'soft' flashing can be applied, without degrading midtones, than with similar-grade exposures. It becomes obvious that, for sheer versatility, variable-contrast papers definitely have the edge on fixed-grade papers.

## Adding Highlight Detail

All this additional exposure does little to add more than faint detail into highlight areas. Many first attempts at flashing prints are overdone, fogging rather than flashing the print and resulting in veiled highlights. An alternative method is to use a flash exposure in combination with a high-contrast burn-in, which is in direct contrast to the more common method of soft-grade burning.

By adding a high-contrast burn-in to the flash exposure, the exposure does not, in itself, add any tone to the extreme highlights of the straight print. Typically, a flash exposure between 2 and 3 stops less than the paper threshold exposure is about right. A subsequent selective burn-in, with filter 5, paints in the lost details of the highlight area, without overemphasizing the effect. Clearly, if a filter 5 was used exclusively in these areas, without support from the flash exposure, by the time the highlights had some print tone, the details would be featureless black blobs.

To illustrate the difference between flashing alone and a combination of flashing and burning, we shall make another study of a brightly lit waterfall. In the first case, we use a basic exposure and a series of low-grade burn-in exposures. Fig.8a-d show, clockwise from the bottom left, the basic filter-2 exposure and increasing amounts of additional filter-00 burn-in exposures applied to the entire image. For simplicity in these mini-prints, the burn-in exposures have been applied to the whole print. We are only considering the highlight tones. Obviously, a final print would have the rocks masked during the soft-grade exposure. The soft-grade burn-in adds water texture to the pool and the cascade. It picks out some details in the brightest highlights but, just as with flashing, it is easy to overexpose and gray the sparkling highlights. The tracery lying across the waterfall is only partially picked out, and the sky still merges in with the bright highlights at the top of the cascade.

The second set of test prints, fig.9a-d, show a combination of the basic exposure, a flash exposure and a hard-grade burn-in. Fig.9a shows the basic 7.2-second exposure with filter 2. Fig.9b shows the combination of the basic exposure and a 2.8-second flash, which brings the extreme highlights to the paper threshold. This flash exposure was determined with a test strip, using a basic print, overlaid with increasing flash exposures of 1.4, 2, 2.8 and 4 seconds, (not shown). In fig.9c and 9d, I have added an 18 and 26-second burn-in with filter 5 to the basic/flash exposure combination. Normally for convenience, the two image-forming exposures are done first, followed by the flash exposure, but this arrangement can be changed, since the order of the exposure is irrelevant.

In the flashed print, fig.9b, detail is added to the pool and to the darker highlight areas, while the rock faces remain virtually unchanged. The hard burn-in exposures, using filter 5, keep the highlight sparkle and yet pick out detail in the cascade and the tracery in a more dramatic way. In the original print, it is now possible to distinguish the sky and water boundary.

For a final print, the filter-5 exposure must be applied with a mask, so that the exposure only affects the highlight areas and does not darken the rock faces. The differences between the highlight qualities of both methods are subtle and may not be obvious on these pages. The method you choose will be dictated by your personal taste, your image and its complexity.

In the former method an additional soft burn-in, which may be quite long with high-density negatives, adds more image forming light, yielding subtle highlight detail. With high-contrast images, these long exposures must be carefully masked to avoid midtone and shadow darkening. For example, in the print above, the sky required 117 seconds of exposure with filter 00 to register some tonality compared with the basic

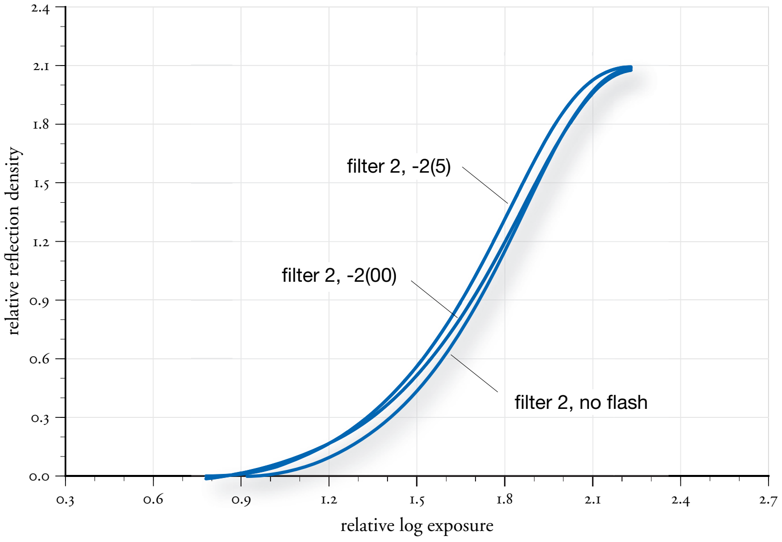


fig.5 These characteristic curves show how flashing with different filters affects a normal-contrast print (grade 2). The hard flash (filter 5) is equivalent to a simple exposure increase, whereas the soft flash (filter 00) modifies highlights and midtones.

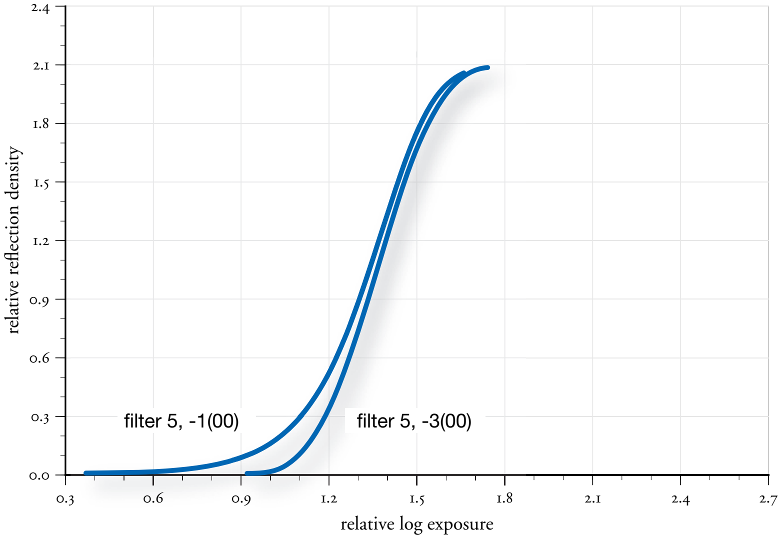


fig.6 These characteristic curves show how flashing with a soft filter (00) only affects the highlights of a hard print (grade 5). Midtones and shadows are not affected. The highlight modification can be controlled with varying amounts of flash exposure.

exposure of 7.2 seconds. This soft burn-in method finds favor with highlights and overlapping tracery such as faint winter trees against a bright sky, which most likely do not require any further darkening.

In contrast, the second method had a brief flash exposure applied to the whole print. This added some detail in the lighter midtones, but left the extreme highlight and shadow tones unaffected. For this reason, the flash method finds favor with complex highlight shapes that defy simple masking.

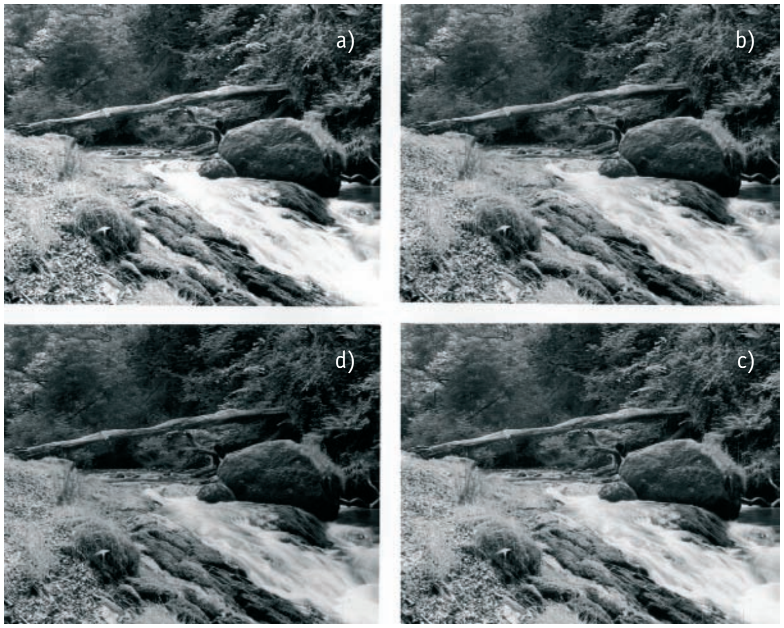
Furthermore, if the flash exposure is kept unobtrusive, so the paper is sensitized to the threshold of detection, then a hard contrast burn-in can be used to add a trace of detail to highlight areas, still, without dulling the brightest highlights. This is especially true and useful for high-contrast scenes, which are subsequently overdeveloped.

## Flashing Equipment

There are two ways to create a flash exposure: use the enlarger as a highly diffused light source or install a dedicated flashing unit. Since suitable flash exposures are typically very weak, the high-intensity light from an enlarger poses a problem. Even with the minimum aperture applied, extremely short flashing times are required to give satisfactory flash exposures. Some printers dedicate a separate enlarger without negative to flashing, and fit it with a low-intensity and highly diffused light source to solve this issue. But, most printers stick to one enlarger and cover the enlarging lens with a plastic or styrofoam cup to reduce the effective light intensity (fig.10). In either case, suitable filtration is required with VC papers to lower the contrast setting of the flash exposure.

Alternatively, a dedicated flash unit may be used as a light source. These units use low power, under-run light bulbs and produce a soft, low-intensity light. Many darkroom workers find dedicated flash units more convenient to work with, especially when they have a built-in timer. Regardless whether you use the enlarger or a dedicated flash unit to create the flash exposure, a reliable exposure timer is required to accurately control and repeat the flash exposure and the inevitable test strips.

fig.7a-d This comparison illustrates how different types of flashing can affect an image:
a) no flash
b) same grade flash
c) soft flash
d) hard flash

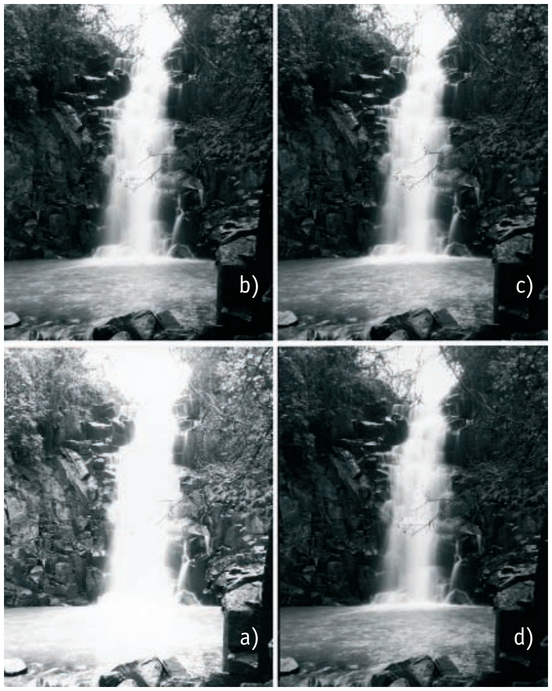


## Safelight Safety

A word of caution about safelight and safety. Because the flash exposure is often applied to the whole of the print, the whole of the print is now susceptible to any additional exposure from safelights. During ordinary printing, a pure white on the print would have remained pure white, because the additional safelight exposure was insufficient to introduce any visible print tone. Now, that the flash exposure has brought the entire paper surface to the threshold of visible tones, any further safelight exposure will produce unwanted highlight appearance. It is good practice to turn off your safelights during the print and flash exposure and to minimize the safelight exposure during print development by turning the paper facedown. One of the advantages of the murky brew sitting in a Nova vertical slot processor is that the safelight cannot reach the print during development.

## Determining the Flash Exposure

Whichever method you use, how do you determine the flash exposure? It is tempting to do a test strip of very small exposures on a blank piece of paper and pick the exposure on the threshold of visible tone. If you do this, it is easy to predict the outcome. Any part of the image with a similar exposure will receive twice the expected exposure and end up quite dark. Even if you reduce the flash by 1 stop, the effect is still quite obvious. This is shown graphically by the curve



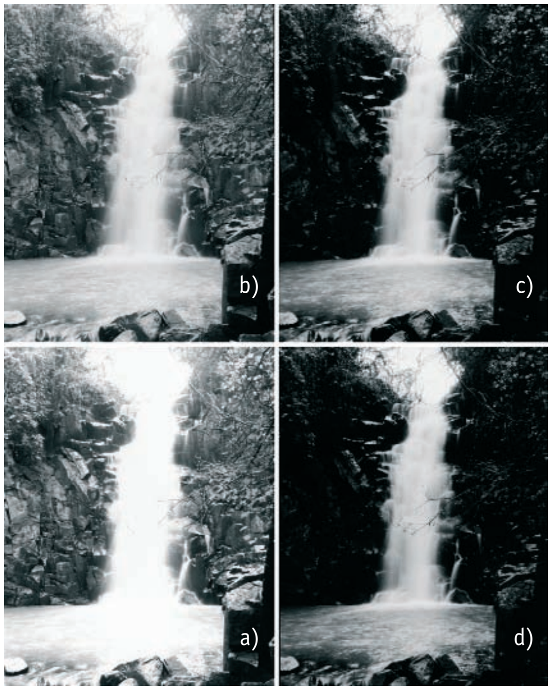


fig.8a-d (far left) This comparison shows the effect on water and tracery, of increasing amounts of soft filter-00 burn-in exposures applied to the whole image. The basic exposure time was 7.2 s with filter 2.
a) basic exposure
b) +15s soft burn
c) +18s soft burn
d) +21s soft burn

fig.9a-d (left) This comparison shows the effect on the same image, of different amounts of filter-2 flash exposure combined with a filter-5 burn-in exposure.
a) basic exposure
b) +2.8s flash
c) +2.8s flash +18s hard burn
d) +2.8s flash +26s hard burn

in fig.1 designated 'grade 2, -1(2)', which indicates a significant darkening of the highlight areas with this level of exposure. More likely, flash exposure values lie in the range between 1.5 and 4 stops less exposure than threshold white. My observations clearly indicate that any flash exposure more than 1 stop less than the paper threshold will result in muddy looking highlights, and the image sparkle is lost.

## Conclusions

Print flashing, along with split-grade printing and paper development controls, are all tools in the arsenal of creative darkroom work. Print flashing, unlike split-grade printing, affects the tonal distribution preferentially in the highlight region of a print. This can be applied globally or selectively to an image and is often successfully used to tame small areas of intense highlights. It can also be applied as an additional support to the burn-in contribution. The tonal effects of flashing on VC papers vary with the contrast setting of the flash. Hence, it is wise to flash with the same, or lower, filter setting to avoid darkening of midtones and shadows. The possibilities with VC papers are endless, but take care with expansive highlight alterations and avoid the all-too-common veil effect. It is easy to illustrate the effects of these creative printing controls. Nevertheless, the difficult part is choosing when to use them, or perhaps more importantly, when not to use them!

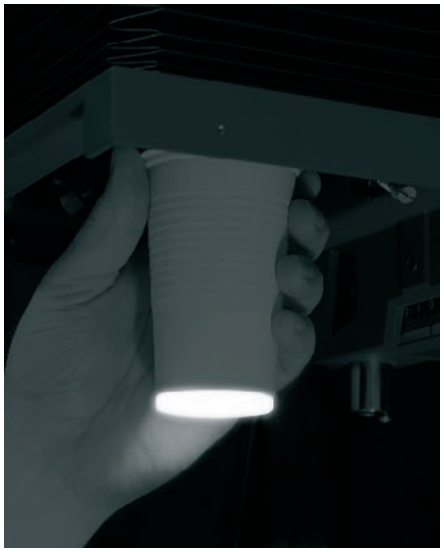
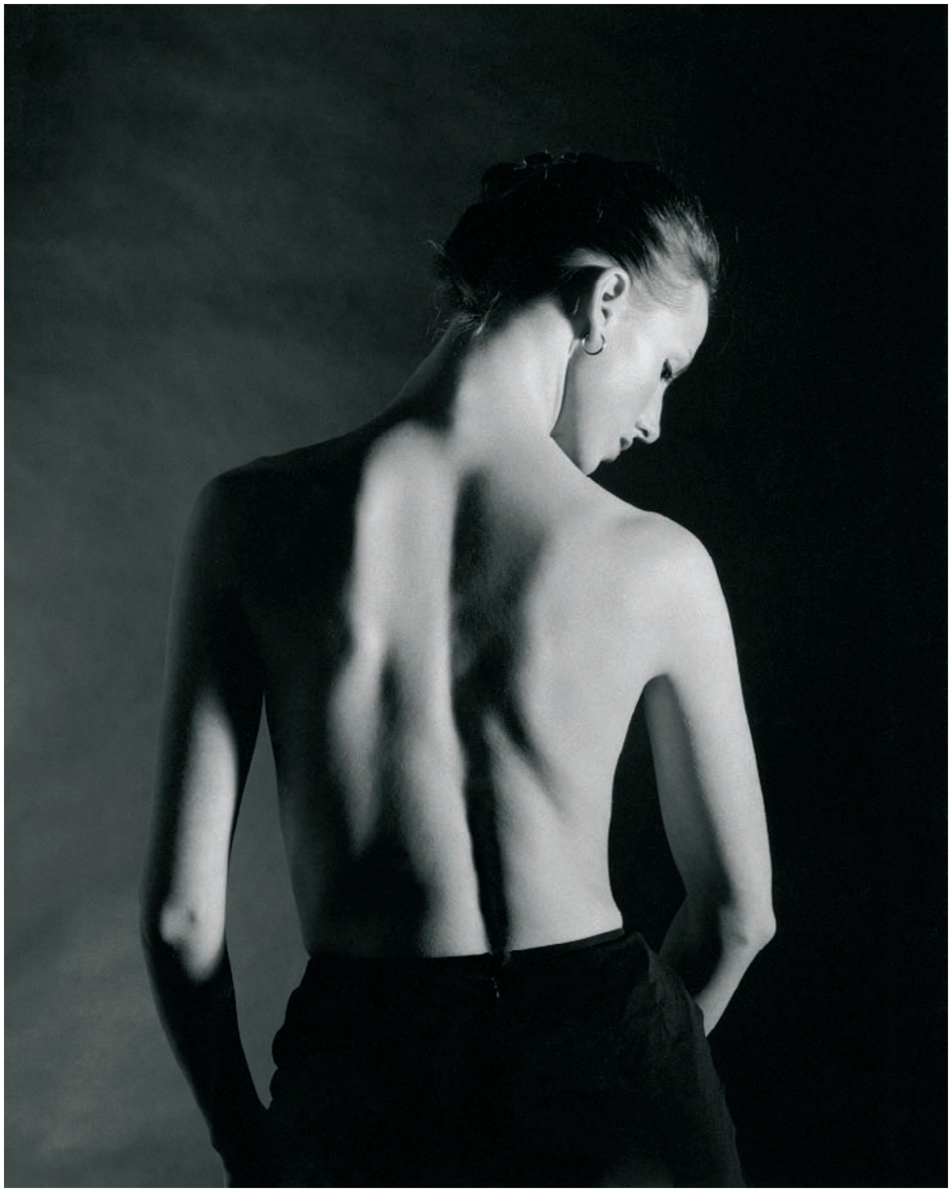


fig.10 Covering the enlarging lens with a plastic or styrofoam cup is an effective way to create a highly diffused light source for flash exposures. The light intensity can be reduced to a minimum by inserting an opaque paper lining into the cup.

# Paper Reciprocity Failure

## Or, why are some prints lighter than expected?



Reciprocity failure is widely acknowledged as a film problem, affecting exposures over 1/2 second. However, reciprocity failure also affects prints, which partially explains why an increase in enlargement often gives a lighter than expected print appearance.

On reflection, this is not so surprising. After all, most print exposures are between several seconds and several minutes in duration. For those printers who use a test strip, this effect is irrelevant. The new test strip at the new aperture or image magnification will take care of the correction. If, however, you use a theoretical calculation, based on optics alone, to determine the difference in exposure between a small work print (8x10 inch) and a larger final print (16x20 inch), then print reciprocity failure can cause an underexposure of up to 1/6 stop with many papers.

Print reciprocity failure is also a problem with easel metering systems, if they were calibrated for an 'average' print. In bright conditions, the meter will slightly overexpose the print, and in dim conditions, with implied long exposure times, the meter reading will slightly underexpose. In some professional meters and timer designs, the exposure time is scaled, and therefore, the effect of reciprocity failure is reduced to less than 1/24 stop per stop, which is more accurate than some enlarging lens aperture markings.

### Measuring Paper Reciprocity Failure

In our test, the method chosen to measure paper reciprocity failure was kept very simple. The test was carried out with several current products, including fast, cool-tone papers and slower, warm-tone papers. For each paper, six contact prints were exposed at fixed aperture, using a calibrated density step tablet and a precision enlarger timer. The first print was exposed for 8 seconds. Then, the exposure time was doubled for each next step, exposing the last print for 256 seconds.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50044-2

The resulting print densities were plotted against their relative log exposures and adjusted by 0.3 log units for each doubling of exposure time. This way, the final photographic effect of several theoretically equivalent exposures was compared.

The results for Agfa Multicontrast Premium are shown in fig.1. For this paper, the log exposure loss over the entire 5-stop range is about 1/3 stop. However, the loss of speed and its related print densities are almost constant for each doubling of time, which is indicated by the fairly even horizontal spacing of the curves. This means, an average exposure adjustment of approximately 1/16 stop per doubling of exposure time is required to maintain consistent highlight densities with this paper. The almost parallel curves also show that the exposure shift is nearly the same throughout the tonal range. A slightly smaller shift in the shadows, compared to the highlight shift, accounts for a contrast increase of only 1/4 grade over the 5-stop exposure range. Consequently, doubling the exposure time by one or two stops will not increase print contrast noticeably. In many cases, the effect of paper reciprocity failure can be compensated through an exposure adjustment alone, without the need for an additional contrast adjustment.

An evaluation of the other papers tested showed very similar results. The range of required reciprocity adjustment varied from 1/12 to 1/24 stop per stop. The faster, cool-tone papers showed less print density loss than the slower, warm-tone emulsions, such as Ilford Multigrade Warmtone. In addition, the experiment was repeated, using shorter exposure times between 1 and 16 seconds, and the reciprocity failure was consistent down to the shortest possible print times, thereby proving that paper reciprocity failure is not a phenomenon limited to long exposure times.

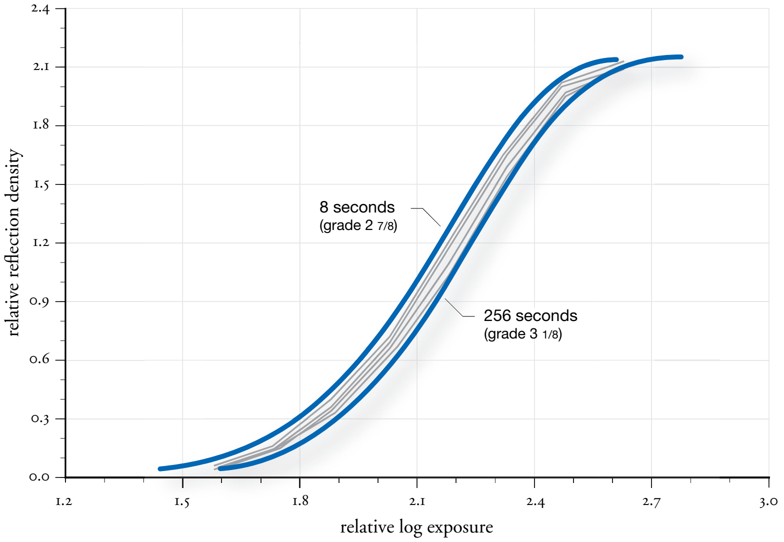


fig.1 The paper reciprocity test revealed a continuous reduction in print density when increasing exposure time from 8 to 256 seconds. The resulting overall speed loss is about 1/3 stop and can be averaged to about 1/16 stop per doubling of exposure time. However, the paper characteristic did not change noticeably with only a slight increase in contrast of 1/4 grade over the entire 5-stop range.

| reciprocity failure | typical values | |
|---|---|---|
| | per f/stop | per 5 stops |
| speed loss | 1/16 stop | 1/3 stop |
| contrast increase | - | 1/4 grade |

When test strips are made for each enlarger setting, reciprocity failure in photographic paper is more of an academic interest than practical application. In the case of professional darkroom meters, an adjusted time scale can do all the hard work of correcting exposures for different image intensities.

# Miscellaneous Material Characteristics

## Stabilizing, removing or understanding noise factors

To fully understand photographic material characteristics and behavior, individual testing is unavoidable. Every brand of film, paper and processing chemical contains different ingredients, and there are too many external influences to make universally valid recommendations. This is why responsible technical authors always propose verifying the key characteristics of your favorite materials with a few tests, and test instructions typically start with the suggestion to only use fresh materials.

Conducting any test with reasonably new film or paper, and processing the exposed material in freshly mixed chemicals makes a lot of sense. Whenever trying to understand basic material characteristics, one is well advised to fix as many variables as possible. Inviting the unknown influence of aging materials into the test introduces unpredictable variation, skews the results and turns firm conclusions into guesswork.

Engineers refer to these unwanted influences as 'noise' factors and invest much effort to find and identify them. If possible, noise factors should be stabilized or eliminated from the process, and if not possible, their influence must be fully understood and their contribution considered. Here are two examples:

Processing chemicals do not last forever. With regular use and age, their chemical activity becomes progressively weaker. Conducting a paper exposure test with fresh developer stabilizes any variation possibly introduced by aging developer and allows for a more reliable conclusion about the paper's response to exposure. It allows to concentrate on the paper characteristics without being influenced by developer exhaustion. Another example is the recommendation to use film developer and fixer only once to remove potential chemical exhaustion as a noise factor in film processing altogether.

© 2004 by Peter De Smidt, all rights reserved

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50045-4

Stabilizing or removing all noise factors is not always possible. For example, it is beyond reason to mix fresh developer for a printing session, if the last session was yesterday and only a few prints were made. It is also ridiculous to scrap a box of paper just because it is a few months old. A more sensible approach is to be aware of miscellaneous material characteristics and to fully understand their contributions by testing for them separately, as seen in the following examples.

### Diluting Paper Developer

An often cited recipe for controlling extreme print contrast is to dilute the paper developer. A quick test on fiber-base paper proved, this is not the correct remedy. Equally exposed test strips were processed in different developer dilutions, using factorial development. The results in fig.1 show that increased developer dilution only reduces the shadow densities but does not control highlight and midtone contrast.

### Aging Paper Developer

Kodak claims that their paper developer Dektol keeps its properties for months while in a closed bottle, but recommends not leaving it in an open tray overnight. A simple test, conducted over the course of a week, proved this suggestion to be rather conservative. Every day, a constant exposure was made, and the fiber-base test strip was processed in the slowly aging developer. The results in fig.2 allow for the conclusion that developer aging has no significant effect for the first two days, after which, the print's Dmax is reduced.

### Latent Image Stability

In a misguided effort to save time, many darkroom workers have developed the habit of exposing a number of prints in one go and then processing them one after the other. This means that the last print's latent image is much older than that of the first print. Fig.3 shows typical values for latent image stability and how it affects paper contrast and speed.

### Aging Paper

Throwing old paper into the trash seems like a waste. The test results in fig.4 prove that paper slowly loses contrast over time, but even after several years, the contrast loss is easily compensated for through a harder contrast filtration. This, of course, has its limits and is only possible with variable-contrast papers.

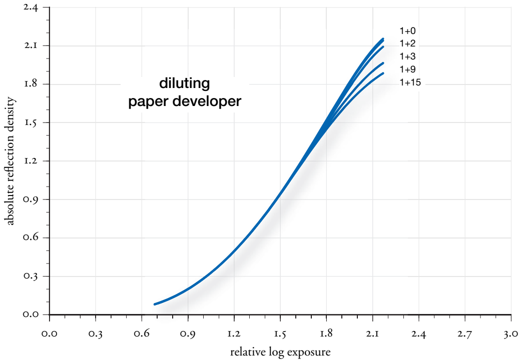


fig.1 Increasing this developer's dilution only reduces the shadow densities but does not control highlight and midtone contrast.

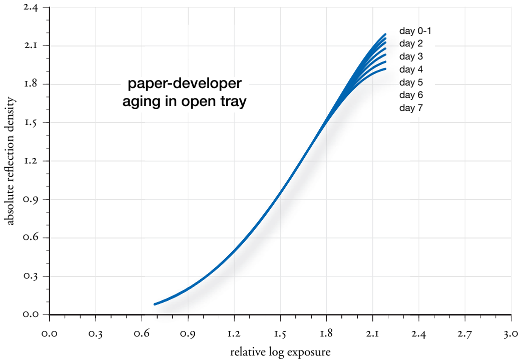


fig.2 Keeping this paper developer in an open tray has no adverse effects for the first two days, but keeping it any longer will limit the print's Dmax.

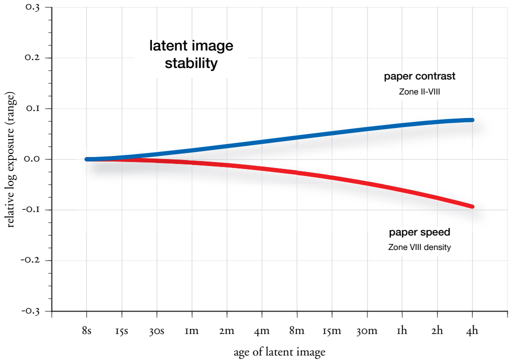


fig.3 Exposing a piece of paper and not developing it right away gives the latent image an opportunity to age, affecting its contrast and speed. Typically, print highlights will gain some density over time, while midtones and shadows remain constant, which is an effect very similar to print flashing with a soft filter.

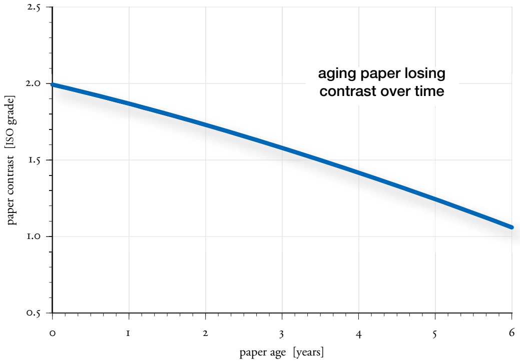


fig.4 Photographic papers slowly lose contrast over time, but with VC papers, this can be offset through a compensating contrast filtration.

# Factorial Development

## Compensating for print development variables

Throughout this book, we suggest modifying the film development in order to control negative contrast, but we always imply that print development is a constant. Some printers change the print development for creative purposes, but we accomplish our image manipulations during the print's exposure or through post-processing techniques and, therefore, prefer to keep the print development consistent. The main process variables of film development are easy to control, but the actual print development constantly varies due to continual changes in developing activity, caused mainly by temperature fluctuations and gradual developer exhaustion. One strategy to compensate for constant changes in print developing activity is to modify the print development time accordingly, which has advanced into an efficient technique referred to as 'factorial development'.

### Development Factor

Factorial development is based on the assumption that all print densities emerge proportionally in the development bath. In other words, the time of emergence for any particular image tone is a fixed percentage of the total print development time. If, for example, it takes 20 seconds for the midtones to appear in a print that is fully developed after 2 minutes, then it will take 3 minutes to fully develop the same print in another developing bath in which the midtones emerge in 30 seconds. In practice, factorial development relies on the photographer noting the emergence time for a specific image tone in the developing bath and multiplying this time by a development factor to determine the total print developing time.

Once established, development factors are constant and do not change with developer activity. When using fresh developer, for instance, the emergence time is short and so is the total development time. Advancing

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50046-6

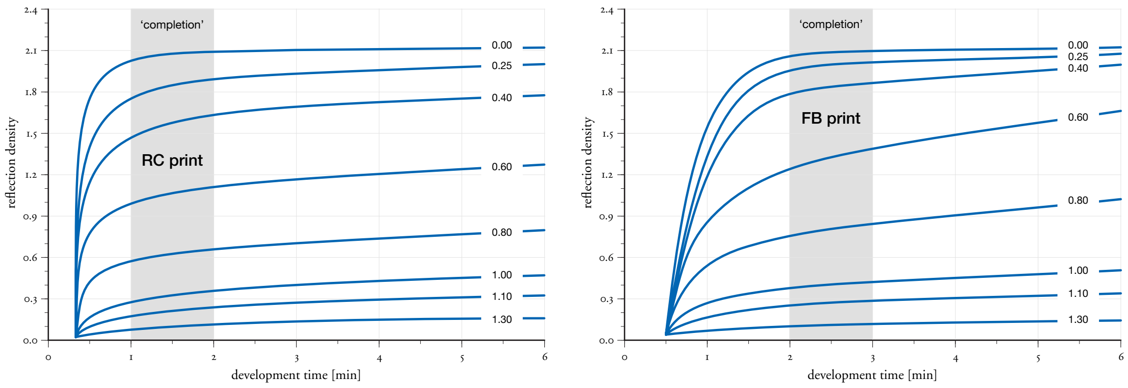


fig.1 Resin-coated papers (far left) develop much quicker, and initially much faster, than their fiber-base counterparts (left), but all image tones rapidly gain print density at first, with the darkest images tones quickly reaching maximum print density. All other image tones gradually, and without any sign of reaching completion, continue to increase in density, if left in the developer.

toward developer exhaustion, the emergence time increases, but so does the total development time. The case is similar for changes in developer activity due to temperature fluctuations. Nevertheless, the ratio between total development time and time of emergence for a specific image tone remains constant. This so-called development factor can be used to compensate for any change in developer activity until the developer approaches exhaustion.

The development processes of resin-coated and fiber-base papers are very similar, but fig.1 illustrates how they differ during initial development. Resin-coated papers develop much quicker, and initially much faster, than their fiber-base counterparts. This makes it difficult to accurately determine an emergence time for any but the darkest image tones, which also explains why factorial development is mostly favored by users of fiber-base paper.

## Establishing a Development Factor

The following calibration procedure is a simple way of determining a standard development factor for one's own materials and workflow: Using fresh developer at the recommended dilution and temperature, put an exposed test print of a step tablet into the developing bath and start a stopwatch. As soon as the first image tones start to emerge, closely observe the area on the step tablet known to have medium to dark midtones. Note the elapsed time at their first appearance. Continue the test print development for the recommended standard time. The standard development factor is calculated by dividing the total development time by the emergence time. From now on, always use the standard development factor as a starting point to determine individual print development factors.

Having established a standard development factor, it makes sense to determine individual development factors for each image, based on using one of the first work prints. It is best to use the first optimized straight print without local exposure manipulations, because dodging and burning exposure will skew the results. As always, print highlights are controlled with exposure, and shadows are mainly adjusted with paper contrast, but the development factor can be altered as required to create subtle contrast changes. The final factor can be used to make many identical looking prints, as it is insensitive to rising darkroom temperatures or slowly maturing developers. It even compensates for the sudden rise in developer activity when exhausted developer is replaced by a fresh bath. In each case, the change in developer activity produces a modified emerging time, which is multiplied by the development factor to determine a new compensating total development time. It is worthwhile to record the individual development factor with each negative.

Factorial development eliminates the inappropriate use of standard development times and ignores the myth of developing to 'completion'. Fig.1 illustrates that all image tones rapidly gain print density at first, with the darkest images tones quickly reaching maximum print density. All other image tones gradually, and without any sign of reaching completion, continue to increase in density beyond practical development factors, if left in the developer.

Factorial development is only as accurate as the selection and evaluation of representative image tones and their emergence time, with shorter times being more sensitive to measurement variation. Typical development factors range from 4-8x (fig.2), beyond which, paper staining and fogging is likely to occur.

| emergence time [s] | development factor | | |
|---|---|---|---|
| | 4x | 6x | 8x |
| **15** | 1:00 | 1:30 | 2:00 |
| **20** | 1:20 | 2:00 | 2:40 |
| **25** | 1:40 | 2:30 | 3:20 |
| **30** | 2:00 | 3:00 | 4:00 |
| **35** | 2:20 | 3:30 | 4:40 |
| **40** | 2:40 | 4:00 | 5:20 |

fig.2 Factorial development relies on the photographer noting the emergence time for a specific image tone in the developing bath and multiplying this time by a development factor to determine the total print developing time.

## Compensating for Developer Activity

Ansel Adams stressed the usefulness of factorial development and gives a detailed description in his book *The Print*. More recent master printers agree and selected the technique as their standard method of operation. We wanted to test the effectiveness of factorial development with modern fiber-base papers and conducted a few experiments, investigating the most typical causes for changes in developer activity.

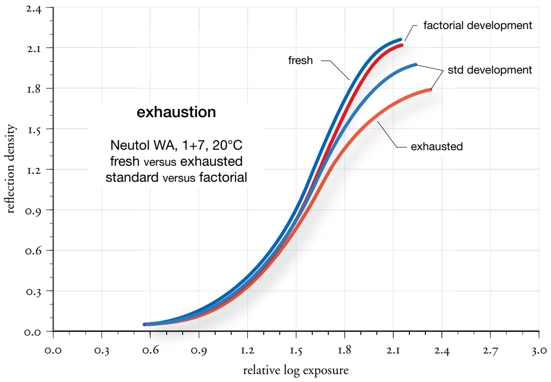


fig.3 Standard development in fresh and exhausted developers produced very different looking prints, neither reaching maximum paper density. Factorial development, on the other hand, produced two nearly identical prints with only a small reduction in Dmax with partially exhausted developer.

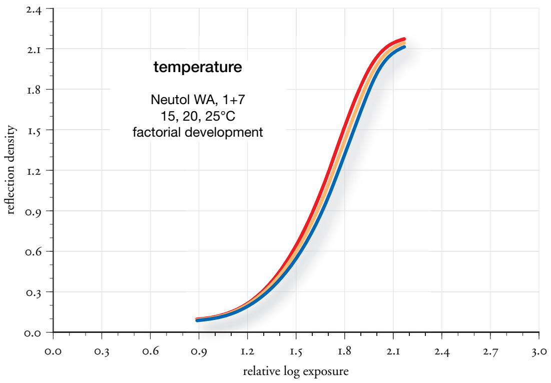


fig.4 The effect of modest temperature differences can be almost entirely compensated for with factorial development, even though the emergence and total development times can be very different.

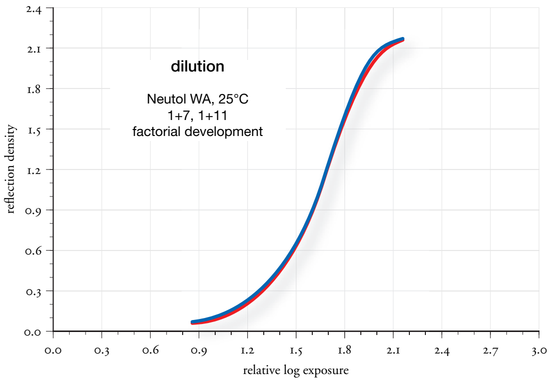


fig.5 Changing developer dilution influences developer activity with several consequences, but factorial development is able to compensate for the effect of different dilutions on print tonality.

### Exhaustion

Every print developer has a limited capacity. After developing a certain number of prints, the developing agents are exhausted, and the developer must be replenished or replaced with a fresh bath. The consequences are gradual, and abrupt changes in developer activity. Fig.3 compares the effect of fresh versus partially exhausted developer against their performances during standard versus factorial development.

After a recommended standard development time of 2 minutes, fresh and exhausted developers produced two very differently looking prints. The developing time was too short for the partially exhausted developer to produce maximum paper density, and even fresh developer failed to deliver its full potential. A 6x factorial development, on the other hand, produced two almost identical prints with only a small reduction in Dmax with partially exhausted developer. Factorial development cannot work miracles, and there is a point at which developer activity is beyond compensation, but it seems that up to an 8x factorial development nicely makes up for aging developer.

### Temperature

Unless you have a large darkroom in the basement or the luxury of an air-conditioned darkroom, it is difficult to maintain a consistent darkroom temperature. In a small darkroom, lighting and body heat alone can raise the temperature by several degrees. This makes tray development with large surface areas prone to variations in developer temperature and activity. Fig.4 shows that the effect of modest temperature differences can almost entirely be compensated for with 6x factorial development, even though the emergence and total development times can be very different.

### Dilution

Changing developer dilution influences developer activity with several consequences. Fig.5 indicates that factorial development is able to compensate for the effect of different dilutions on print tonality.

Factorial development is an effective means to compensate for changes in developer activity in order to produce consistent print appearance. In practice, many photographers choose development factors between 4-8 for fiber-base printing. The trick for consistency is to choose a medium to dark midtone and train yourself to reliably identify its emergence time.

# Print Bleaching

## From a mediocre rescue attempt to eye-catching improvements

Finding the perfect highlight exposure and the optimum overall image contrast is the best foundation for a fine print, but it is rarely enough to produce outstanding work. Almost all prints benefit from some local exposure and contrast enhancements, which highlight what is important and subdue what is not. These improvements are commonly achieved through strategic dodging and burning of the print in the darkroom under the enlarger, and the results, typically, speak for themselves. But now and again, something still seems to be missing. To me, that 'something' is almost always an eye-catching brilliant highlight at the center of interest.

Ansel Adams once said that a successful photograph needs all print tones as little as a good piece of music needs all notes. It might be a matter of taste, but I have to disagree with the master on this one issue, and his own fantastic images prove the point. His most impressive photographs include all print tones from a rich black in the deepest shadows to a brilliant white in the highlights. And in many cases, it is only due to those bright highlights that a print comes 'alive'. Brilliant highlights create interest and pull the viewer into the picture. They enhance the print by providing sparkle and visual impact. However, dodging and burning are not always the right tools for intensifying these small, but important, highlights. A powerful alternative is the application of bleach.

### Liquid Light

Print bleaching is a very effective darkroom technique, and I prefer to use potassium ferricyanide, 'ferri' or 'liquid light' as it is sometimes called, for this purpose. You can buy it separately as a yellow powder or together with fixer as Farmer's Reducer, but note that a few ounces go a long way. Following the formula in the appendix, I mix 10 g of the powder with 1 liter of water

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50047-8

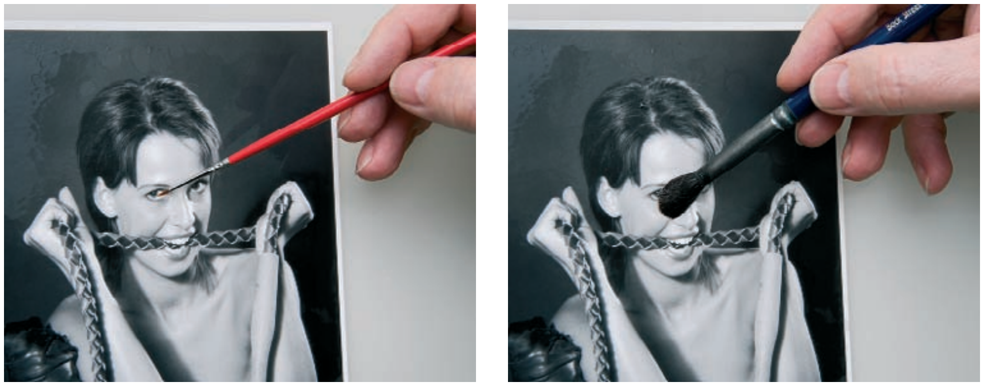


fig.1 After fixing and washing, wipe excess water off the print and apply bleach to muddy highlights with a small brush (left). Leave it to work for a few seconds, and then, remove bleach and silver with a large brush, soaked in fixer (right). Hose the print down and repeat the process until highlights have the desired sparkle.

to make a 1% stock solution. This stock solution is then mixed 1+1 with fixer to make a working solution and applied with a brush to the area to be bleached.

Unfortunately, the working solution is not very stable due to a chemical reaction between ferri and fixer, causing it to lose its entire strength within 10-15 minutes. Consequently, I prepare only a small quantity of working solution at a time and make more as I need it. Alternatively, ferri and fixer stock solutions can be used in sequence, as shown in fig.1. This is my preferred method when working on intricate print detail, such as eyes and teeth in portraits, because the acid fixer is rather unkind to my expensive spotting brushes. However, the bleaching effect is only visible after fixation, and unintended over-bleaching is not uncommon when ferri and fixer are used in sequence. The immediate density reduction of the fixer may come as a surprise to the inexperienced worker.

To get started, fill a small beaker with 25 ml of ferri stock solution and another with 25 ml of regular fixer, as seen in fig.4. Right after fixing and washing, place the damp print onto a horizontal surface. You can also work on a previously processed and fully dried print, but then soak it in water first. Wipe excess water from the area to be treated, and carefully apply a small amount of ferri to the highlights, using a small spotting brush. Leave it to work for a few seconds and make sure it does not run into bordering image areas. Then, remove bleach and silver with a large brush soaked with fixer, hose the print down, and repeat the process until the highlights have the desired sparkle. Keep a close eye on the highlights, and repeat the process until the desired effect is achieved. If at all possible, keep a wet duplicate print nearby for comparison. Fig.2 shows the effect of highlight bleaching eyes and teeth after several applications.

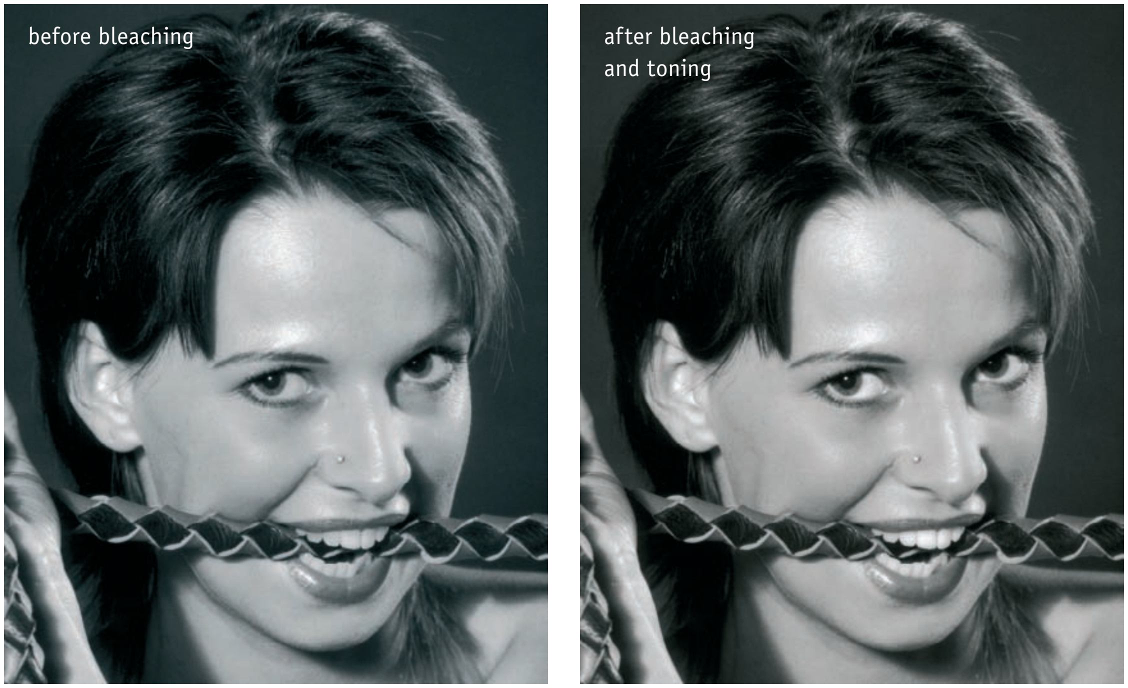


fig.2 Applying a little bit of 'liquid light' to eyes and teeth, prior to toning, made this print come 'alive' and provided much needed visual impact.

A comparison print allows you to better judge the bleaching progress, so that it is not overdone, which is especially disturbing if the viewer can compare the image with experience, as is the case with portraits. Fig.5 shows a borderline bleaching effort to an otherwise very natural portrait. Some practitioners struggle with the fact that bleaching is a sluggish process at first. Often, impatience quickly takes over, and the bleach is applied for too long or too often to get speedier results. It is best to stop before highlights are where you want them to be. As seen in this example, if taken too far, some features do not look natural anymore.

During the process, I prefer to keep the print on a horizontal glass surface, because any runoffs will leave unrecoverable telltale marks. Keep in mind that any accidental spills will have the same effect. After all highlights have been improved to satisfaction, fix the print in fresh fixer one more time to make sure that all bleached silver is entirely removed, and continue with your normal print processing procedure.

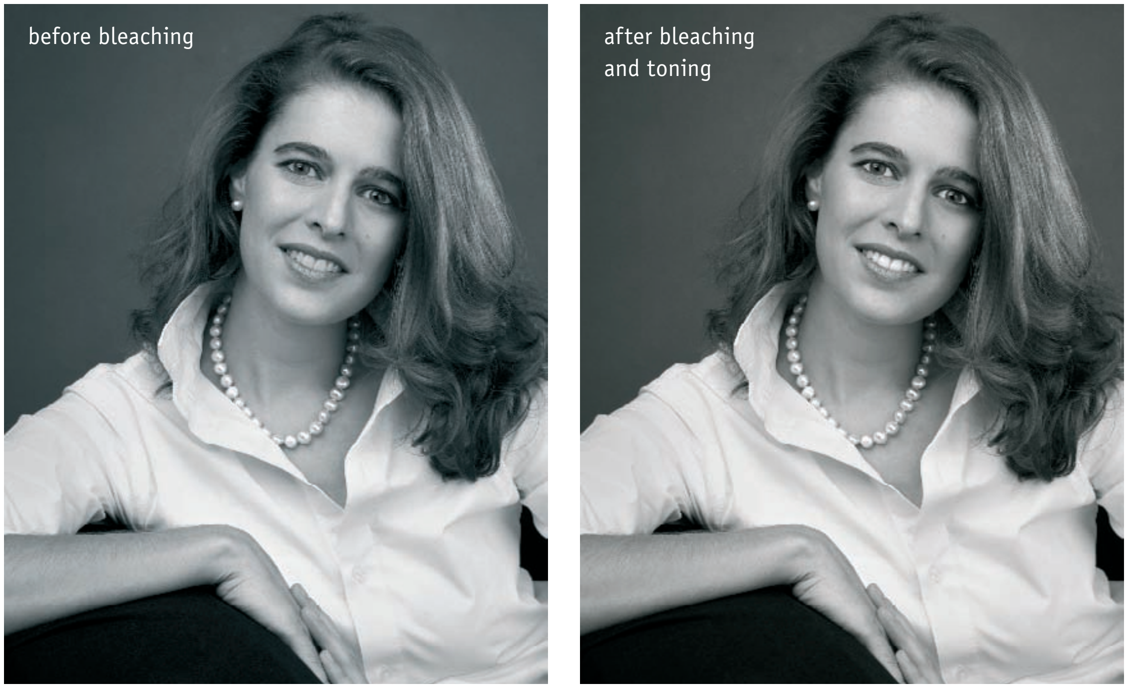
The images shown in this chapter demonstrate the impact of bleaching on eyes and teeth in portraits only as an example. But, this is not the only application for this useful technique. Local and overall bleaching can be used to improve many different print exposure and contrast issues. I use print bleaching on a regular basis to strategically draw attention to the key areas of the print, provide sparkle to highlights, open up otherwise dull shadows, and improve local contrast whenever dodging and burning alone do not give me what I want. In 'Rape Field', another example of how a little bit of 'liquid light' can significantly improve the appearance of clouds in a landscape is presented. There, it adds crucial impact and turns a simple image into a dramatic print. Print bleaching is a valuable technique where other contrast-increasing methods are either too limited, difficult or impractical to apply, as demonstrated for the case of energetic eyes and white teeth.

## Bleach, Toner and Archival Processing

Toning is a chief contributor to archival print processing, because the toner converts the image forming metallic silver, which is vulnerable to environmental attack, to a more inert silver compound. In the case of selenium and sulfide toning, this compound is silver selenide and silver sulfide, respectively. Bleaching is the direct opposite of protecting the image silver,

Kodak
potassium
ferricyanide
(anhydrous)
Net Weight 5 Pounds
2.27 kg
CAT 146 3327

fig.3 Potassium ferricyanide, 'ferri' or 'liquid light' as it is sometimes called, is a very effective darkroom tool used for print bleaching. It can be bought it in bulk as a yellow powder or ready-mixed as Farmer's Reducer, but a few ounces will go a long way.



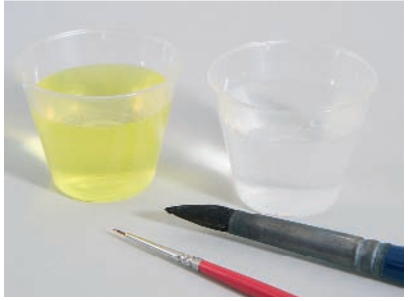


fig.4 Two small beakers, filled with ferri and fixer, allow for the sequential application of both chemicals.

fig.5 The portrait on the left would benefit from more highlight sparkle, but the result on the right illustrates how easy it is to overdo the procedure.

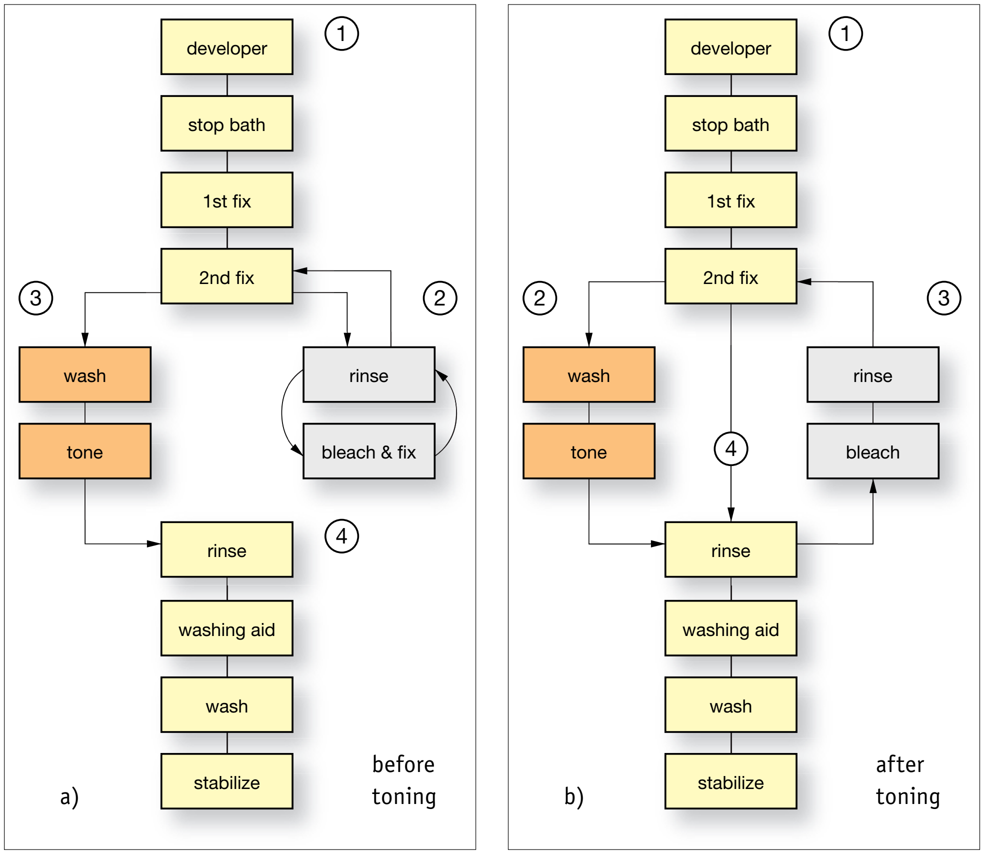
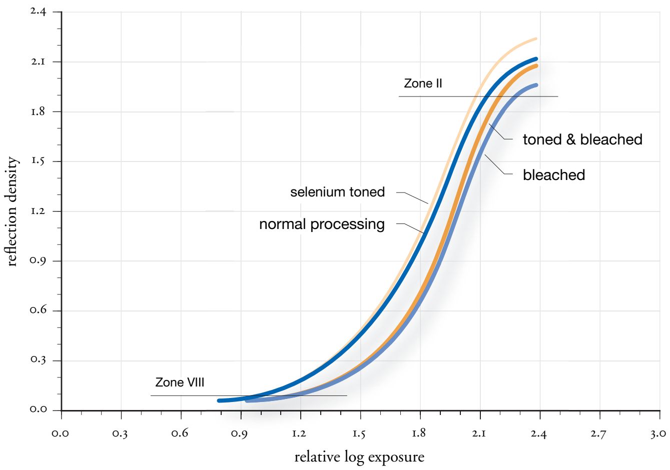


fig.6 Bleaching is most powerful if done before toning (a), but it can also be done after or between different toning applications (b). For archival processing, it is recommended to always treat the whole print in a fresh fixing bath after bleaching. This removes all unstable silver halides that are potentially left behind by the bleach-and-fix solution.

fig.7 Bleaching after toning can add unique value. For example, bleaching a selenium-toned print creates an image with bright highlights and increased shadow contrast, without significantly affecting the darkest image tones.



because it converts the developed metallic silver back into silver halide. This can be made soluble and washed out with regular fixer, just like the unexposed and undeveloped non-image silver in the print. A toned image, on the other hand, largely consists of the more inert silver compounds above, and is therefore less affected by the bleach. In fact, a mild bleach is one way to test the effectiveness of the toner protection.

This already answers the question of whether to insert bleaching before or after toning into the archival print process. Bleaching is most powerful if done before toning (fig.6a), but it can also be done after toning or between different toning applications (fig.6b).

Bleaching after full selenium and sulfide toning makes little sense, because the image protection is very strong after such treatment. However, there are some cases where bleaching after toning adds unique opportunities. For example, bleaching after selenium toning has the benefit of protecting midtones and shadows from the bleach up to a point. In other words, bleaching a selenium-toned print reduces highlight densities and increases shadow contrast while maintaining maximum print density (fig.7). This creates an image with bright highlights and increased shadow detail, without significantly affecting the darkest image tones. This treatment can be continued with subsequent sulfide toning for increased image protection.

Toning by itself leads to an unavoidable, but often desired, change in image tone. Bleaching the print before or after toning takes this color change into a new and unpredictable direction. However, the additional bleach influences how the toner affects the print color in different ways, depending on bleach-toner sequence. Bleaching prior to toning often adds a yellow tint to all image tones, where bleaching after selenium and sulfide toning comes with an obvious shift towards warmer image colors. Final print tones depend heavily on the amount of bleaching, as well as the type of toner, bleach and paper. Uniform tonal changes, as a result of bleaching the entire print, are usually of little consequence. Nevertheless, heavy local bleaching may result in unsightly staining but is easily predicted through prior testing. The effect of bleaching on archival processing is not fully understood, but it is recommended to always treat the whole print in a fresh fixing bath after bleaching. This removes all unstable silver halides that are potentially left behind by the bleach-and-fix solution.

# Print Dry-Down

## The immeasurable myth?

fig.1 Highlights are sensitive to the dry-down effect. A print may look darker and duller when dry, but a combination of exposure compensation and toning can cure the problem.

Fine photography, as previously suggested, is in many ways like high fidelity music reproduction, with the same diminishing returns for increased expenditure and difficult objective measures of quality. Witness the many audio tests, with their blind listening panels and fancy electronic testing. The subjective and objective assessments often don't correlate, or worse still, two pieces of equipment measure identically and sound different.

The print dry-down effect falls into this category. As the name suggests, print dry-down is the change in print appearance between its wet and dry state. This change is difficult to measure with a densitometer, leading many to deny its existence. For the discerning photographer, however, this change can make all the difference between success and failure, and for many others, it is the cause of disappointment from unexpected drab results.

For some printers, this transformation never occurs, because each test strip and each work print is dried before evaluation. Therefore, the print assessment is carried out with the final dry product. This may be convenient for quick drying, resin-coated paper, but for fiber-base prints, which take considerably longer to dry, evaluating only dry test prints can be a tiresome constraint. Ansel Adams used a microwave oven to expedite drying, but this is not necessarily a representable technique for every paper.

However, trying to rush the print evaluation by using a damp print is not an option. Test prints and work prints require the same attention to tonal detail as the final print. The recommendations for print evaluation and viewing conditions are amply covered in the chapter 'Fine Tuning Print Exposure and Contrast'. To be sure that our final dry print is tonally correct, we need to allow for the dry-down effect and use a consistent evaluation light source. I use a ceiling

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50048-X

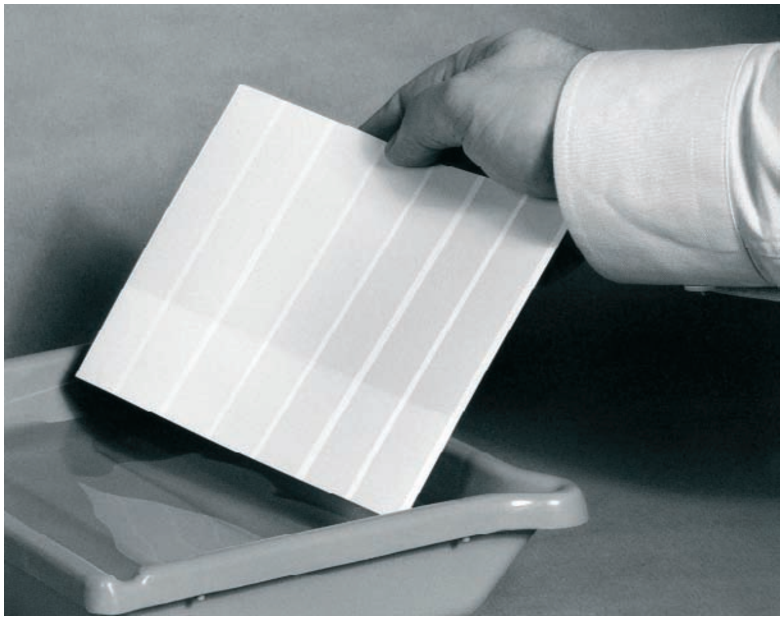


fig.2 A quick test can make the dry-down effect clearly visible. The test print was exposed in 1/12-stop increments around a highlight density of Zone VIII, processed normally and then fully dried. Re-wetting part of the print allows wet and dry densities to be compared. As a rule of thumb, highlight densities are about one increment darker when dry.

mounted, 100-watt opal tungsten light bulb, which is located about 2 meters from the print, in my own darkroom for a reliable print assessment.

## Practical Assessment

Print dry-down is difficult to quantify in simple terms, but its principal effects can be compensated for during the printing process. If we were to compare several prints, on different papers, wet and dry, and in different lighting conditions, we would see that print tones change in different ways and with different papers to different extents. For this reason, it is not practical to give exact results, but to give advice on practical personal assessment. Luckily, dry-down is reversible, so one can easily appreciate the effects with a previously dried grayscale, which has been dipped partially in water (fig.2).

To make such a grayscale, set up an enlarger without a negative and with the lens set to a working aperture. Make a test strip in 2/3-stop increments. Understanding exposure changes in f/stops is useful for later on, since the correction for dry-down is easily described in f/stop adjustments. With a standard timer, expose each strip for the following times: 4.0, 6.3, 10.1, 16.0, 25.4, 40.3 and 64.0 seconds. With normal contrast paper, it should be possible to capture a wide range of tones, from the very pale to the near black. Develop, fix, wash and dry this print normally. Then, dip one half in water for 20 seconds, and just blot the excess water off so that each print density has a dry half and damp half, with a clear boundary between the two. Each time I do this, the difference still surprises me.

## Gleaming Gem to Mud Brick

An objective assessment of print dry-down requires a detailed comparison between wet and dry print reflection densities across the entire tonal range. The result of the tonal transformation from a wet to a dry print is illustrated by the ‘wet print’ line and the ‘dry print’ curve in fig.3. Taking paper white on the left as the starting point, it is unlikely that you will notice a change. This is the same, using either resin-coated or fiber-base papers. Moving along the scale from off-white to light gray, the wet print looks increasingly brighter than its dry counterpart. Further along the scale, into the dark shadow print values, the wet print is at first similar and then darker than the dry print. With darker highlights but lighter shadows, the dry print has lost contrast and brilliance.

The main print-tone controls at our disposal are exposure, contrast and Dmax enhancement by toning. It can be useful to assess the dry-down effect in these terms. Let us revisit the wet and dry print in terms of correcting highlights, midtones and shadows through exposure, contrast and toning.

## Highlights

A dry print is simply darker, or duller, than its wet counterpart. Highlight contrast is slightly decreased in a dry print, and bright highlights degrade to a pale gray. As we have already discussed in previous chapters, the eye is particularly sensitive to print values in the highlights, more so than a densitometer. Consequently, the most obvious correction is a slight reduction in exposure. This amount can be determined with a simple test print for the highlights, made in the same way as before, but this time with small f/stop increments of 1/12 stop. The test print must be almost paper white at one end and pale gray at the other. With a standard timer, expose each strip for the following times: 8.0, 8.5, 9.0, 9.5, 10.1, 10.7 and 11.3 seconds, or use any sequence from the f/stop-timing exposure table in ‘Tables and Templates’. Using normal-contrast paper, it should be possible to capture highlight print tones around Zone VIII, from the very pale to a light gray.

Take this dry print and dip half its width in water. Let the emulsion absorb water for 20 seconds, and then, remove it and blot off the excess liquid. Now, quickly before the print dries, select your principal highlight tone on the dry side of the test print. Compare the brightness of this with its nearest equivalent tone on the wet side and note the exposure difference. Evaluation can be made easier by direct, side-by-side comparison. In this case, cut the test print in half lengthways, dip one piece in water, and then, slide the two halves alongside one another. Note the exposure reduction required to make the final dry print look the same as the wet work print. Typical values range from -1/12 to -1/6 stop, or an approximate 5% to 10% reduction in exposure time. This correction can be noted for future use with this particular paper.

## Midtones

The effect of dry-down on print midtones varies. Fig.3 indicates how light tones become slightly darker as they dry and that darker tones stay the same or get lighter. There is no easy remedy to cancel this effect. In many ways, midtones are always the poor relation in printing, since our metering and printing techniques often concentrate on the tonal values of highlights and shadows. A small reduction in exposure, for highlight compensation, will also improve most midtones. The exposure change will lighten the midtones appreciatively, since midtones are sensitive to exposure, and therefore reduce the dry-down change in this area. Its effect (blue line) is to move the 'dry print' curve downwards so that it straddles the 'wet print' line.

## Shadows

The eye is less sensitive to shadow density deviations, and many printers ignore the dry-down effect in these areas, preferring to simply reduce the overall print exposure to ensure correct highlight tones. Even so, a reduction in print exposure only adds to the degradation of shadows. Fig.3 indicates how dry-down already produces a loss in maximum print density and, therefore, a reduction in local contrast within the shadow tones. Cutting back on print exposure reduces shadow densities and contrast even further. If the loss of shadow depth and detail is unacceptable, selenium toning and a shadow enhancement, through split-grade printing or an increase in paper contrast, are potential remedies to get the shadows back.

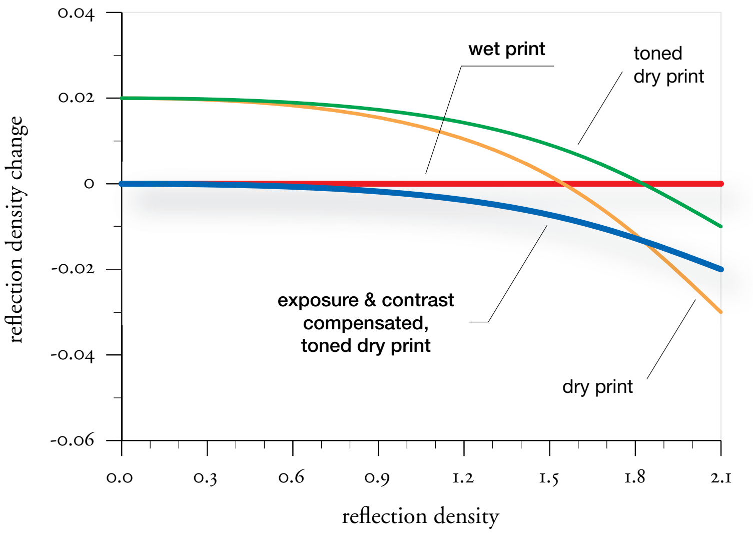


fig.3 While drying, a print often loses much of its original appeal, because of inconsistent changes in reflection density. As a basis, the wet print densities are shown as a horizontal line. After the print has dried, highlight densities become darker and shadow densities lighter. Toning will recover much of the shadow densities, but it also darkens the midtones. This is eliminated if the print exposure is reduced prior to toning. An additional contrast increase will reduce the tonal differences between wet and dry print.

Selenium toning is often recommended to protect prints from aging, but it can also be used to increase apparent contrast and maximum black, or Dmax. Care is needed here, because if toning is prolonged past the point of intensification, the shadows will change color to brown or maroon-black and sometimes even lose density. As a starting point, Kodak Rapid Selenium Toner, diluted 1+19 and used at room temperature, will give an appreciable intensification to shadow areas within a few minutes. The exact time and concentration may be determined with a few experiments on work prints.

Another possibility is to use split-grade printing to enhance shadow separation and depth. As described in the dedicated chapters on this technique, dodging throughout the soft exposure, followed up with a filter-5 burn-in, will add some density to shadow regions and increase local contrast. Although the maximum black does not change, the local contrast increase gives the 'kick' back to the print.

Dry-down is a phenomenon that does exist, and its effect often surprises the unwary printer. Its transitory nature and subtle effect make it difficult, if not impossible, to measure, using a regular reflection densitometer. Dry-down is a cause of much frustration when wet prints transform into dull memories overnight, but much of the original sparkle can be protected through exposure and contrast compensations, as well as selenium toning.

© 2000 by Ralph W. Lambrecht, all rights reserved

# On Assignment

This page intentionally left blank

# Above Malham Cove

## Depth-of-field markings

Yorkshire in general, and Malham Cove in particular, are quintessentially English. This series of desolate moors and curious exposed limestone plateaus, eroded over time, pull a constant stream of visitors like a magnet. These limestone 'pavements' are found in several locations in Yorkshire and also appear in a similar form in western Ireland. The exposed rock surface features deep vertical fissures, which can trap the unwary in good weather and are positively lethal in snowy conditions. I used my second visit to this unusual natural landscape as a chance to try out a new 43mm lens on my Mamiya 7 rangefinder camera. It is impossible not be influenced by the many wonderful existing photographs of the Yorkshire Dales, and my simple treatment of this image was unconsciously influenced by the subtle landscapes of photographer Fay Godwin.

### Keeping It Simple

My mind's eye pictured an unusual stone feature set against a diminishing pavement and background. As I walked around the plateau, weighing up the visual potential of each stone in context to the surrounding scene, it was difficult to find any particularly distinctive stone. Eventually, I found a solitary fern hiding in a fissure, which I placed off-center in the foreground. Unfortunately, it was necessary to remove distracting evidence of modern civilization, so I first picked the surrounding litter. My initial challenge with this unfamiliar lens was to determine the aperture and focus setting required to keep both the fern and the distant hill in acceptable focus. Using the classic depth-of-field markings, which have unfortunately disappeared from many modern lenses, I set the hyperfocal distance by placing the infinity mark opposite the selected aperture, minus 2 stops. Fig.2 shows how to set the hyperfocal distance and how it distributes the depth of field, so the extreme points are in acceptable focus.

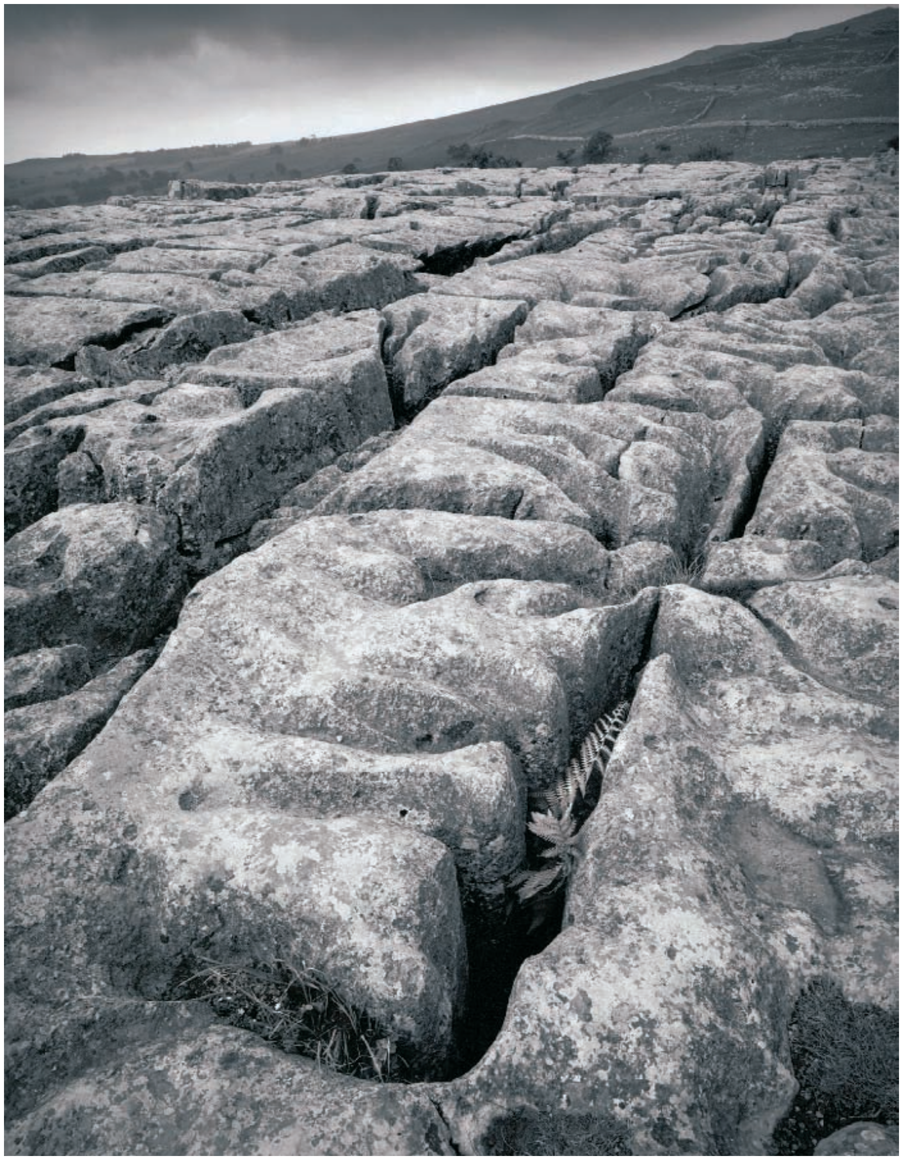


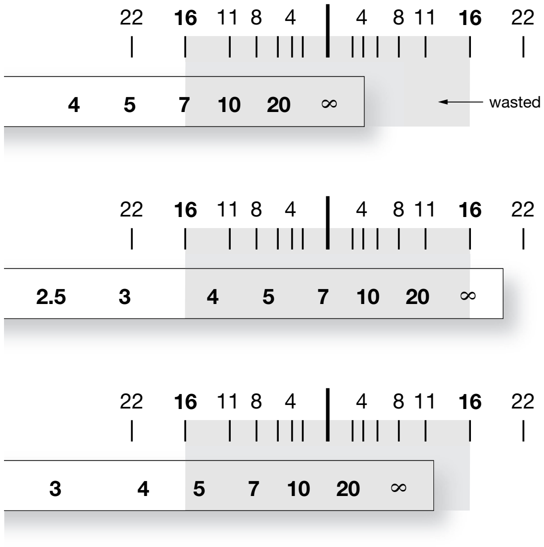
fig.1 Final print on Agfa Multicontrast Premium, burned, bleached and selenium toned

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50049-1

fig.2 a) Focusing on infinity and stopping the lens down to f/16 will provide a depth of field starting at the hyperfocal distance (7 m), but half of the depth-of-field potential is wasted.

b) Focusing on the hyperfocal distance, by matching the right f/16 marking with infinity, optimizes the depth of field but leaves distant objects at the threshold of sharpness.

c) However, stopping the lens down to f/16 and aligning the infinity mark with the right f/8 marking secures distant-object sharpness with a 2-f/stop 'safety factor'.



As discussed in 'Sharpness and Depth of Field', sharp focus is, strictly speaking, limited to the focus plane. Any subject detail in front of or behind the focus plane is out of focus. In practice, however, sharp focus begins at the front limit of the depth of field. With the lens focused at 'infinity', this front limit of the depth of field is referred to as the hyperfocal distance (fig.2a). A lens focused at the hyperfocal distance provides sharp focus from half that distance to 'infinity'. The standards for acceptable focus differ between manufacturers, and more importantly, they differ according to the photographer's needs.

Fig.2 shows a few examples of how the hyperfocal distance is used and how the depth of field can be controlled with the distance and aperture markings on the lens barrel. Medium and small-format lenses have very different depth-of-field scales. A 35mm negative requires approximately twice the enlargement of a medium-format negative to produce the same size image. A corresponding reduction of the circle of confusion is required to produce a similar level of sharpness at the extremes of the in-focus range. Even so, taking the format into account, you will discover that different lens manufacturers use different quality assumptions for their lenses, which result in different depth-of-field scales for similar focal-length lenses.

One disadvantage of working with the hyperfocal distance to determine depth of field is that distant objects are left at the threshold of sharpness. Where this is critical, as in landscape photography, I recommend using a 2-f/stop safety factor to secure overall sharpness, an example of which is shown in the third depth-of-field illustration in fig.2c.

## Print Visualization

The scene above Malham Cove had a pleasing composition and was lit through the natural diffuser of low clouds. The light cast soft shadows and gave interesting form to the weathered rocks. However, the background clouds were very bright and the foreground rock texture quite subtle, making for a high contrast scene. A perfect print, retaining sky detail and accentuating the foreground textures, would be difficult to achieve without some print manipulation, and heavy filtration was not an option, since I could not afford the loss of film speed with this handheld shot.

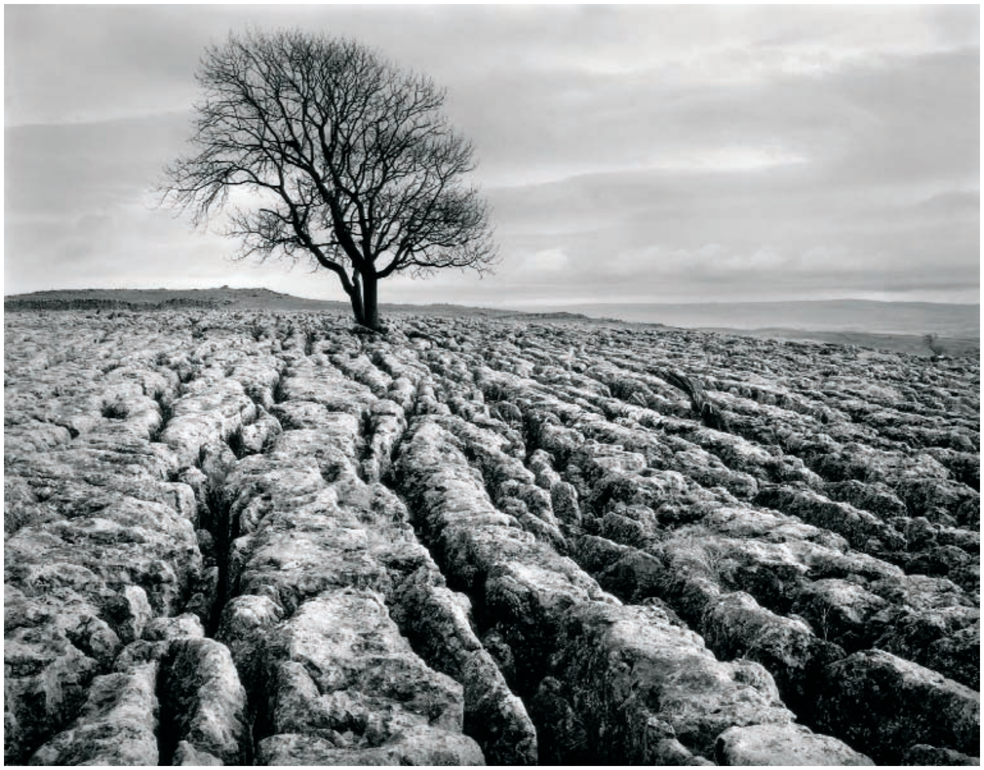


fig.3 Photographers have always been attracted by the limestone plateaus of the Yorkshire Dales, and this location near Malham is no exception. It is not easy to find and hard to get to, but well worth the trip alone.

The only remaining alternative was to create a normal negative and manipulate the image in the darkroom. I took a shadow reading from the lower fissure and reduced the exposure by 3-stops to place the shadows on Zone II. The film was XP2 Super, so I let the extensive film exposure latitude and the shoulder roll-off that standard C41 processing offers take care of the highlights.

## Printing

A straight print of the negative, as shown in fig.4, required a filter-2 contrast setting on Agfa Multicontrast Premium. In this print, the light rock and the brightly lit sky draw attention away from the fern. This print required a balancing of image tones to create mood and guide the viewer's eye. Using a derivative of split-grade printing, the entire scene was exposed for 10.1 seconds with filter 2 with a further exposure through filter 5 in the middle area to emphasize the rock texture and show a full range of tone. In the final print, the fern was gently bleached, after fixing and washing, in a solution of Farmer's Reducer to emphasize its delicate fronds.

The fissures run in all directions, potentially leading the viewer's eye out of the picture. To suppress distracting edge detail, I made several further print exposures at a lower contrast setting to darken the rock highlights and bring out cloud detail. A flexible red card was used to fade in the filter-0 exposure. Using a red card as a burning or dodging tool is advantageous, because it is light enough to show an image on its back, yet reflects only light that is harmless to the paper. A 1/4-stop increment test strip over the rock and sky regions determined a 1/2-stop burn-in exposure with filter 0. My favored edge-burn technique is building up the exposure by a series of fanning sweeps with the red card. A foot-switch allows the card to be in place from the start of these exposures. I keep the card moving to avoid telltale halos.

The sky had only faint detail and did not convey the feeling of imminent rain, which is a fact of life in this wet part of England. Burning down the sky for 1/2 stop with filter 0 added the necessary drama. Again, the bent red card was used in a series of sweeps to avoid telltale straight-line demarcations on the print, to which the eye is particularly sensitive. The final print, fig.1, was toned in selenium. A 1+9 concentration was used to enhance the Dmax of the paper and change the cold shadow print tones to warmer blacks.

Besides improving print longevity, toning is a way for the photographer to convey a desired mood and emotion. In this case, I preferred a suitable warmer print tone for this earthy image and used the no-longer-manufactured Agfa Multicontrast Premium paper, which took on a very attractive warm tint in selenium toner. Warm tones are also made possible using dedicated warm-tone papers, or other neutral-tone papers and sepia toning, but they often turn into a less natural plum-brown color after selenium toning. Since each paper tones differently, the paper choice is often dictated to the practitioner by the image colors created through the available toners.

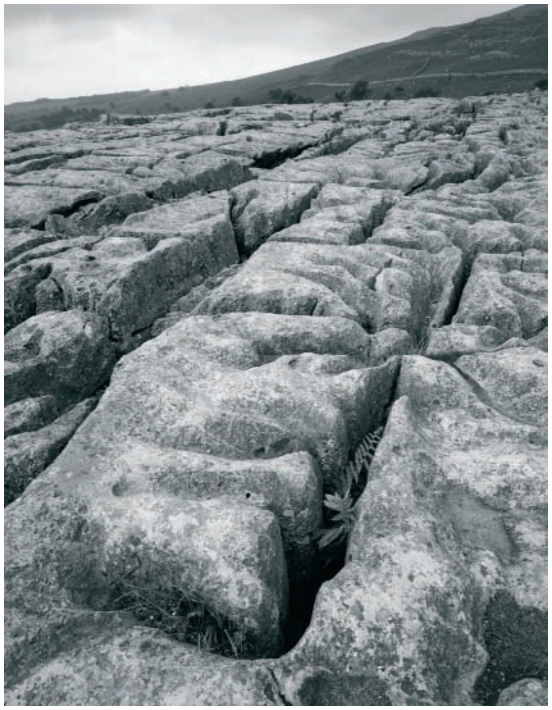


fig.4 (left) This is the straight print using filter 2. Some print manipulation is required to emphasize the stones.

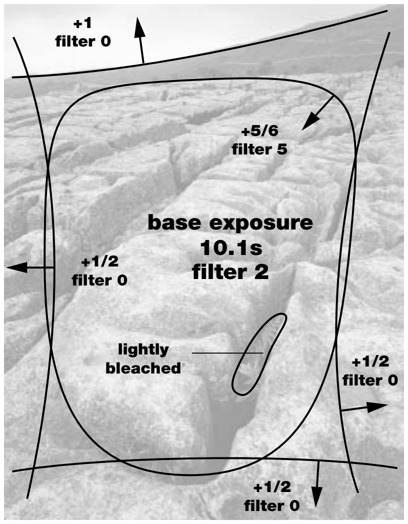
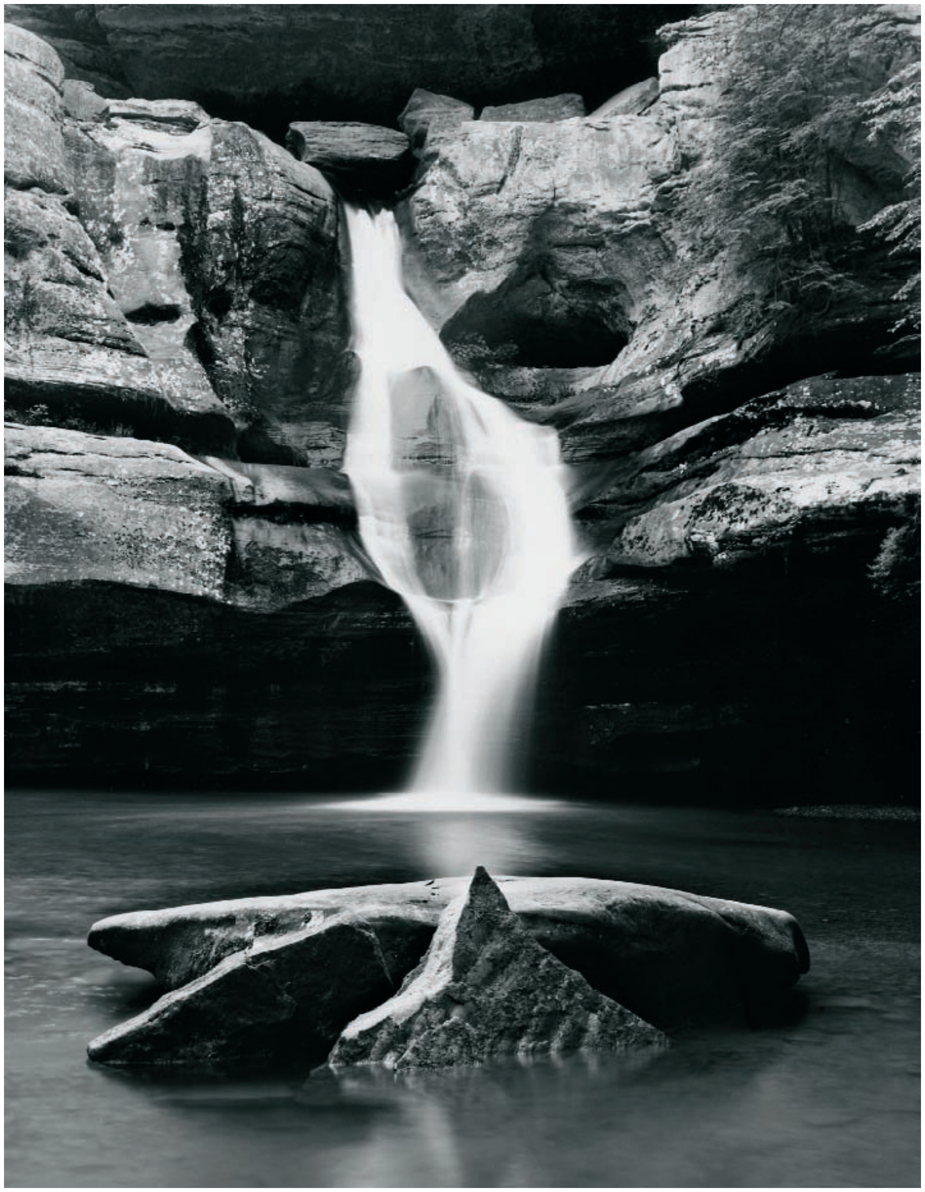


fig.5 (above) The printing map identifies the bleached area and records the burning exposures in f/stops.

# Cedar Falls

## With the help of a custom burning mask

by Frank Andreae



Water covers a majority of the earth, and while most of it simply appears flat and stretched out over the lakes and oceans, in many cases it can be found flowing over stones in a stream, or cascading down mountainsides with great power. Ever changing due to rain or melting snow, these waterfalls produce an abundance of photographic opportunities. One such place in the United States, contained within a state park in Ohio, is called Hocking Hills.

Although Ohio is mostly thought of as a flat state containing much farmland, there is actually a system of gorges and rivers flowing through its boundaries, while making their way to the Mississippi. Here I have come across many falls within a five-mile radius, and in particular, one named Cedar Falls. In June of 1997, while traveling through Hocking Hills, I noticed that the water levels were still high from the spring thaws, and a storm that week had dropped more rain onto the ground, producing a fall of great beauty.

Armed with both my Linhof Technikardan 4x5 and the Mamiya 645 Pro, I walked around this fall trying to find a way to convey its beauty and rugged terrain. I have photographed many waterfalls around the world, and after a while, they start to look the same. At this fall, I was especially intrigued with the rocks lying in the shallow pool, and positioned myself in line with the unique triangular shaped stone, which leads the viewer upward into the cascade of water.

It would be a partly sunny day, but at eight o'clock in the morning, the sun had not yet risen above the trees. As I faced eastward, I determined that the sun would come up over the trees, illuminate the top of the rocks and then continue to shine right into my camera lens within half an hour. I composed my image and metered the dark rock wall in shadow as an EV 5 2/3 on my Pentax Digital Spotmeter. The rock slopes away, and is in deep shadow, but a few highlights remain,

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50050-8

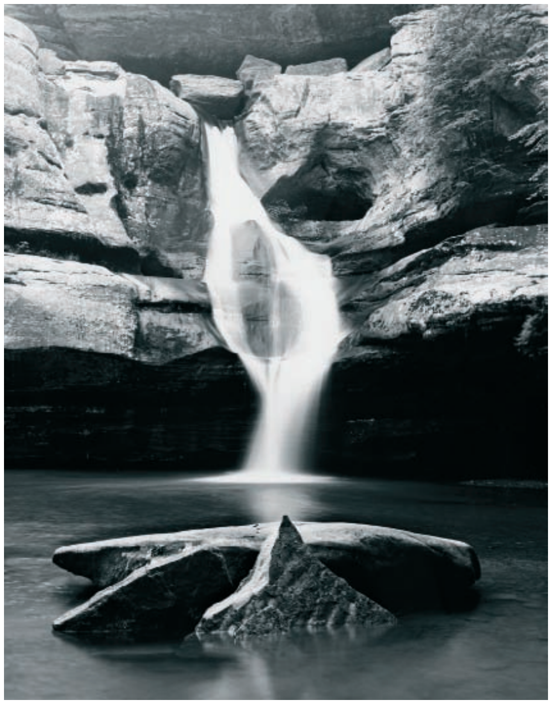


fig.1 This straight print is properly exposed for the shadows but suffers from burned-out highlights and lacks the desired depth. All detail is present in the negative and burning down the highlighted rocks will certainly enhance the mood of the waterfall.

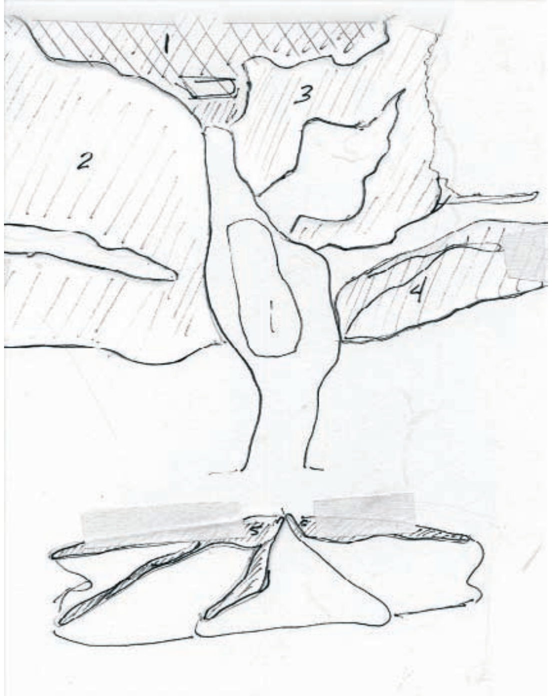


fig.2 A custom burning mask is created to allow precise areas to be given additional exposure. By placing a piece of thick mat board above the print easel and tracing the projected image, the specific areas can be later cut out and hinged for repeatable burns on future prints.

and I wanted these visible to give the image depth. I placed them in Zone III and took a light reading of the water flowing around the right side of the rock in the middle of the composition. Here, I was reading EV 9 2/3, and falling on Zone VII, it would require a normal development. I could also get a little detail from the water, though I knew that with a longer exposure it would blend together and end up a little brighter. For Kodak's TMax-100 film at f/22, I had a 2 1/3 second exposure. I added 1 2/3 second for reciprocity and exposed the film for 4 seconds. This gave some flowing movement and would be well exposed to work with in the darkroom. As I packed up the Linhof, I noticed that I had packed a 120 roll of Kodak's Tech Pan film in my case. I usually carried a roll with me, just in case, but very seldom actually shot with it. Here was my opportunity to experiment.

The scene was very nice, but it lacked the dramatic impact that I wanted to portray in the gorge. I was surrounded by walls of rock and trees on three sides with no other photographers around. The water was flowing well, but I wanted it soft against the harsh rock. The early morning light was starting to fade as the sun was rising closer to the treetops. The tops of the foreground rocks were getting brighter, and wanted more contrast. I loaded the Tech Pan film into the Mamiya and checked my exposure. I determined that an 8 second exposure at f/22 would give me the desired effect, and I shot the first frame with a focal length of 70 mm. As a back up, I added 4 seconds to my exposure time and took a second shot. By this time, the sun was breaking through the trees and was starting to illuminate the top of the rock. I was done.

When I developed my film and produced the contact sheets, I was pleasantly surprised to find that my assumptions were correct. The 4x5 negative held a nice image that captured the scene, but the first image on the roll of Tech Pan film had great potential. The film holds the basis for the life of the print, but the printing process gives it birth. With this negative, I wanted to tone down the highlights on the tops of the foreground rocks, as well as the stone around the falls themselves thus giving most attention to the water. By burning down these areas, I would achieve the final image I was looking for, but to do it precisely meant cutting a mask for each area to be burned.

My test prints had determined that five areas needed a burn-in to achieve the results that I had visualized. I used thick mat board sized a little larger than the print itself, in this case an 11x14-inch print was to be made. After focusing the negative, I placed the mat board on top of the print easel and projected the image. On the board, I traced the major areas of the image such as the waterfall, foreground rocks and stone areas around the fall, paying close attention to the areas I planned to cut out. This yields a pencil drawing of the photograph to work from. I cut out each area with a sharp knife, angled slightly so that the piece of board cannot fall though the opening when closed. Each piece is hinged and tested for ease of opening but tight fit.

With my Zone VI variable contrast cold-light dialed to 'E/F' for the soft and hard settings (similar to a 2. 5-contrast filter) I got a 28-second base exposure at f/8 on the Kodak's Polymax Fine Art double-weight glossy paper. After reducing the hard setting slightly from 'E' to 'D', I gave a burn-in exposure to each area according to the printing map in fig.4. An additional corner- and edge-burn helped to maintain the viewer's eye from wandering outside the image.

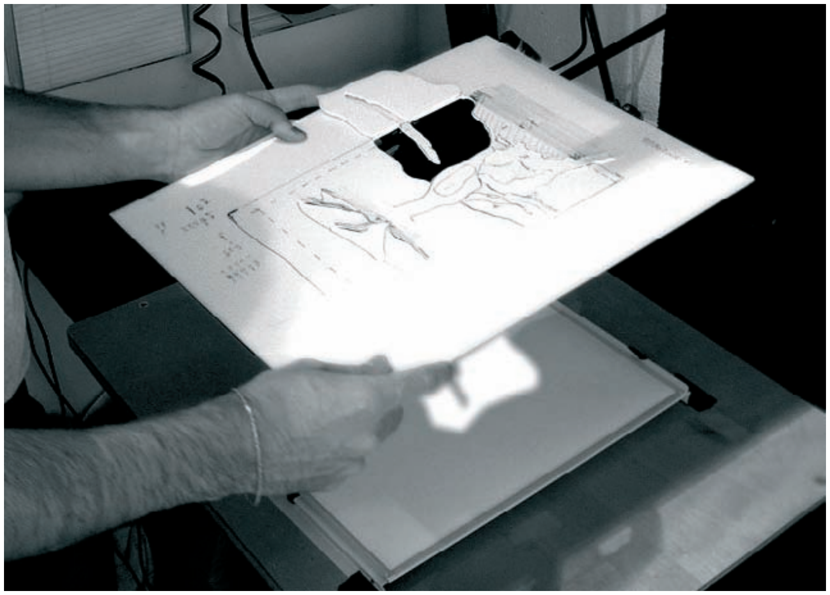


fig.3 With the upper left burn-in area of the mask opened, the print receives the additional 2/3-stop exposure, as tested. The precise cut restricts the exposure to the highlighted rocks. Carefully keeping the mask in motion during exposure will hide otherwise disturbing telltale signs.

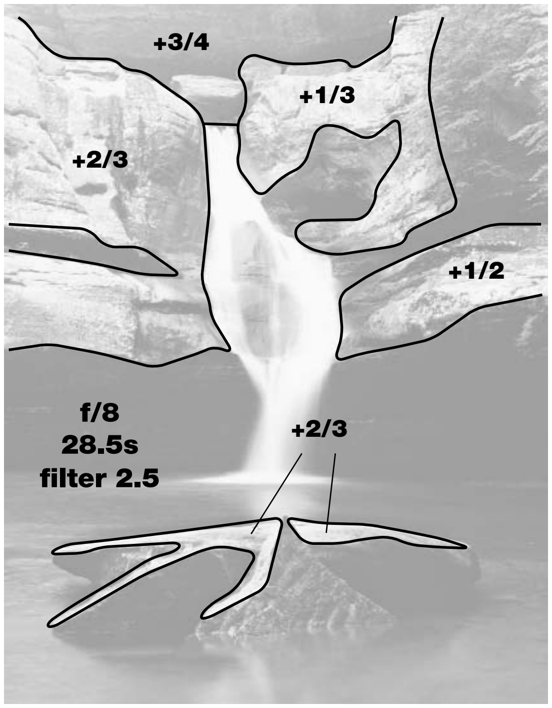


fig.4 The final print exposure map, as determined by test strips and working prints, records the printing instructions for the base print and the five burn-in areas for future use.

# Clapham Bridge

## An example in split-grade printing

It is ironic that one of my favorite images from my 35 mm days was taken with the worst lens I have ever owned. It only took two films before I identified serious aberrations and terrible color fidelity. In the early days of zoom lenses, the standard zoom of the 20 to 80-something variety were optically worse than their fixed focal length cousins. Their use, however, was popular with many walkers, for the dramatic improvement on portability and convenience that they provided.

In this case, I was walking through Yorkshire in England, starting from the delightful village of Clapham, following the Clapham Beck towards Trow Gill, fully laden with waterproofs and supplies. Bitter experience and weary limbs dictated that camera equipment had to be small and light, or it was left behind. Yorkshire is a magnet for many photographers and walkers. Often the two pastimes do not go hand in glove, especially when your companion is a walker. A keen eye is needed for an image opportunity, slippery rock and the path ahead, all at the same time. Thankfully, an obligatory chocolate-stop allowed the opportunity to make the most of this idyllic scene.

### Exposure

The camera was a trusty old Contax RTS II, with the anonymous zoom lens set to 28 mm, loaded with Ilford Delta 400. The oversize filter thread and the threat of vignetting dissuaded the use of filters. I used the center weighted metering with the zoom lens set to 90 mm, measured under the arch and returned to the 28 mm setting, reducing the exposure by 2 stops. I wanted the water to show movement, but I needed to avoid camera shake. Three handheld frames were taken, all with the same exposure, but with increasingly smaller apertures and slower shutter speeds. By taking the frame at the end of an exhalation, I was

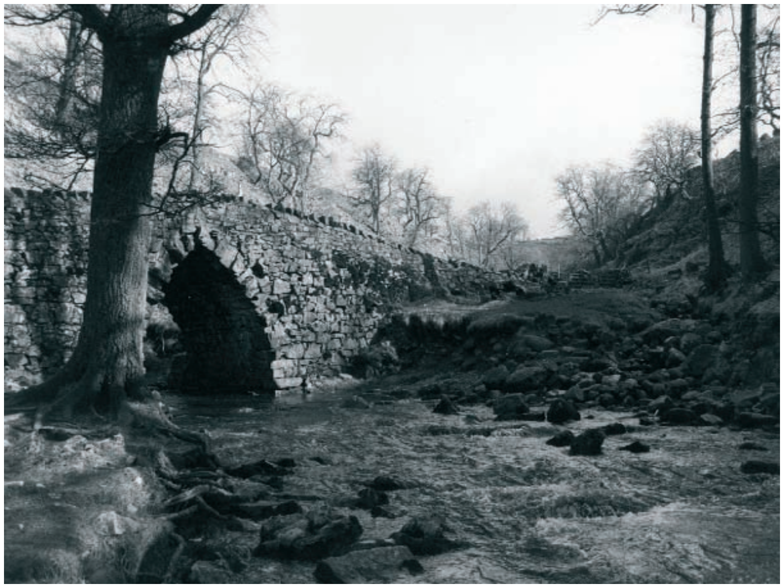


fig.1 straight print, filter 2.5, 6.7 seconds, Agfa Multicontrast Classic

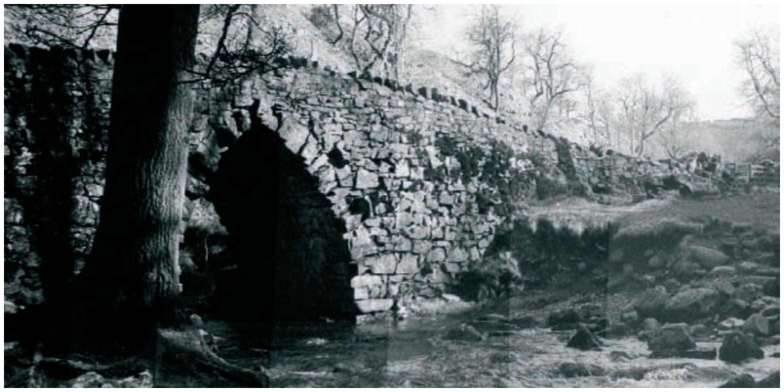


fig.2 split-grade test, filter 00, 2.1 seconds, plus filter 5, starting at 4.2 seconds in 1/3 stop-increments

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50051-X

fig.3 (right) Basic split-grade print with first exposure at 2.1 seconds filter 00, plus a second exposure at 8.5 seconds filter 5. Notice how the sky has gone blank white and the bridge has become more dynamic.

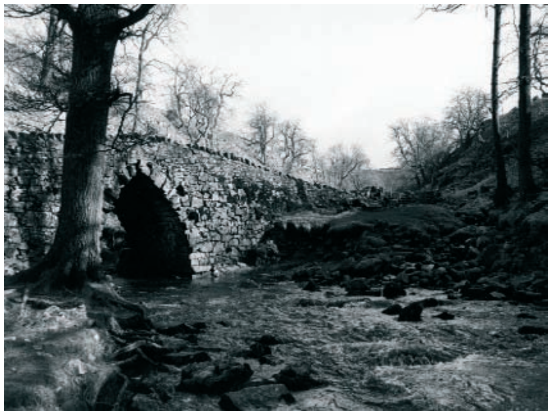
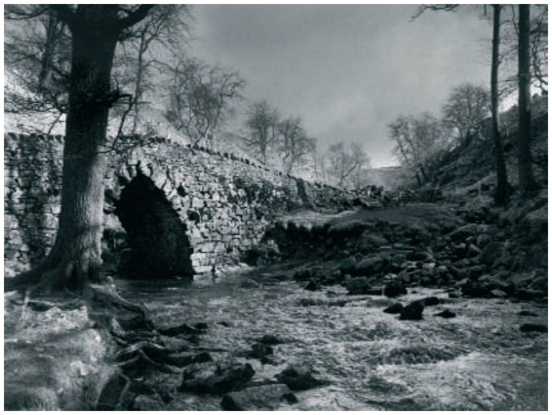


fig.4 (far right) Basic split-grade print, water dodged during first exposure, sky and tree tops dodged during second exposure. The sky was burned down for an additional 3 1/3 stops with filter 00.



fortunate to obtain a sharp image with a 1/15 second exposure. Today, I take along a Leica mini tripod as a shoulder stock or my carbon-fiber tripod on all but the longest treks.

## Processing and Printing

Film development was with my then standard soup of Ilford Ilfotec HC, diluted 1+31, for 9 minutes at 20°C. The negatives showed good shadow detail and a dense sky area, from the bright flat cloudy sky, typical of the sort that frustrates the landscape photographer. A straight print is shown in fig.1. The exposure and contrast were chosen here to show the information on the negative. An evaluation of this image shows several weaknesses, starting with the bright, featureless sky. Since the trees on the hillside cross the horizon, a simple burn-in exposure to the sky area would darken the treetops unacceptably. The bridge and beck lack sparkle, and there is no depth or feeling to the picture. Visually the eye follows the water, right out of the picture. I realized that the only way to get a satisfactory print was to use variable contrast paper and use different contrast settings for different parts of the image. This might be done by combining separate exposures, or more easily, by selective dodging during a split-grade exposure.

The next image, fig.2, shows a test strip for the split-grade exposure. Here the stone highlights were determined with an enlarger meter and printed in with filter 00. A test strip using filter 5 was overlaid on top of this filter-00 exposure to set the overall contrast, tonal separation and shadow definition to the bridge. The straight split-grade print is shown in fig.3 and is made up of 2.1 seconds with filter 00 and 8.5 seconds with filter 5.

To make things easier, the two timing channels of the StopClock enlarger timer were used to store these base exposures. These two times and any burn-in sequences at either filter setting could then be selected quickly, saving valuable time and confusion.

Turning our attention to the sky, the plan was to mask the sky area, including the treetops, using a bent card during the hard-grade exposure. This reduces the print density of the dark branches in preference to the basic sky tone. Now, in theory, the sky could be darkened with a soft-grade burn-in exposure, using a soft-grade setting, such that the treetops looked tonally balanced with their bases and with a considerably darker sky density. For this, a test strip was used with a basic +2 stops filter-00 exposure, and 1/3-stop exposure increments at the same filter setting. The treetops are matched with the tree bases from fig.3 and the correct burn-in exposure was determined. In this case, an additional 3 1/3-stop exposure was required with filter 00.

Fig.4 shows the fruits of this approach. In fig.4, I dodged the water for 50% during the 2.1-second soft-grade exposure to lighten the highlights and add sparkle. Then, without changing filter, I used a rough card mask to subject the sky to another 3 1/3-stop burn-in. Now, during the 8.5-second hard-grade exposure, I masked the sky area with a rough, moving mask to lower the density of the treetops. Even so, the water was still flowing out of the picture and the sky lacked weight. In fig.6, the exposure was completed, using a floppy mask and a further 2 1/2-stop burn-in along each edge, through filter 00. This darkened the highlights without adding much shadow tone. In addition, the witness mark on the main trunk was disguised with a further filter-5 exposure of 1 stop through a hole in a piece of card. Lastly, the gate in the middle was dodged briefly for 1/3 stop during the main filter-5 exposure to add a feeling of airy light.

Finally, the print was briefly toned, washed, lightly bleached, washed and then toned again in variable sepia toner, using 1 part toner and additive to 9 parts water. Apart from the archival qualities that sepia toning bestows, for me, the warm tone imparts a timeless feeling to this tranquil scene and gives a painterly feel.

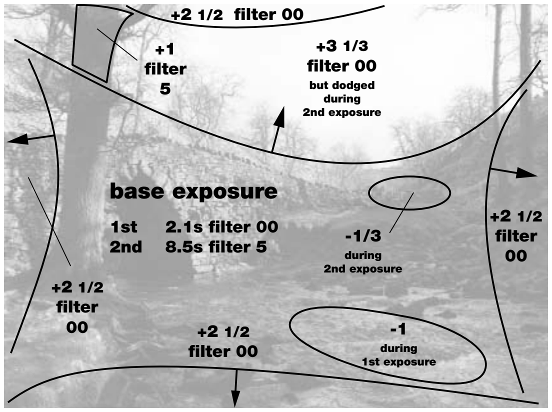
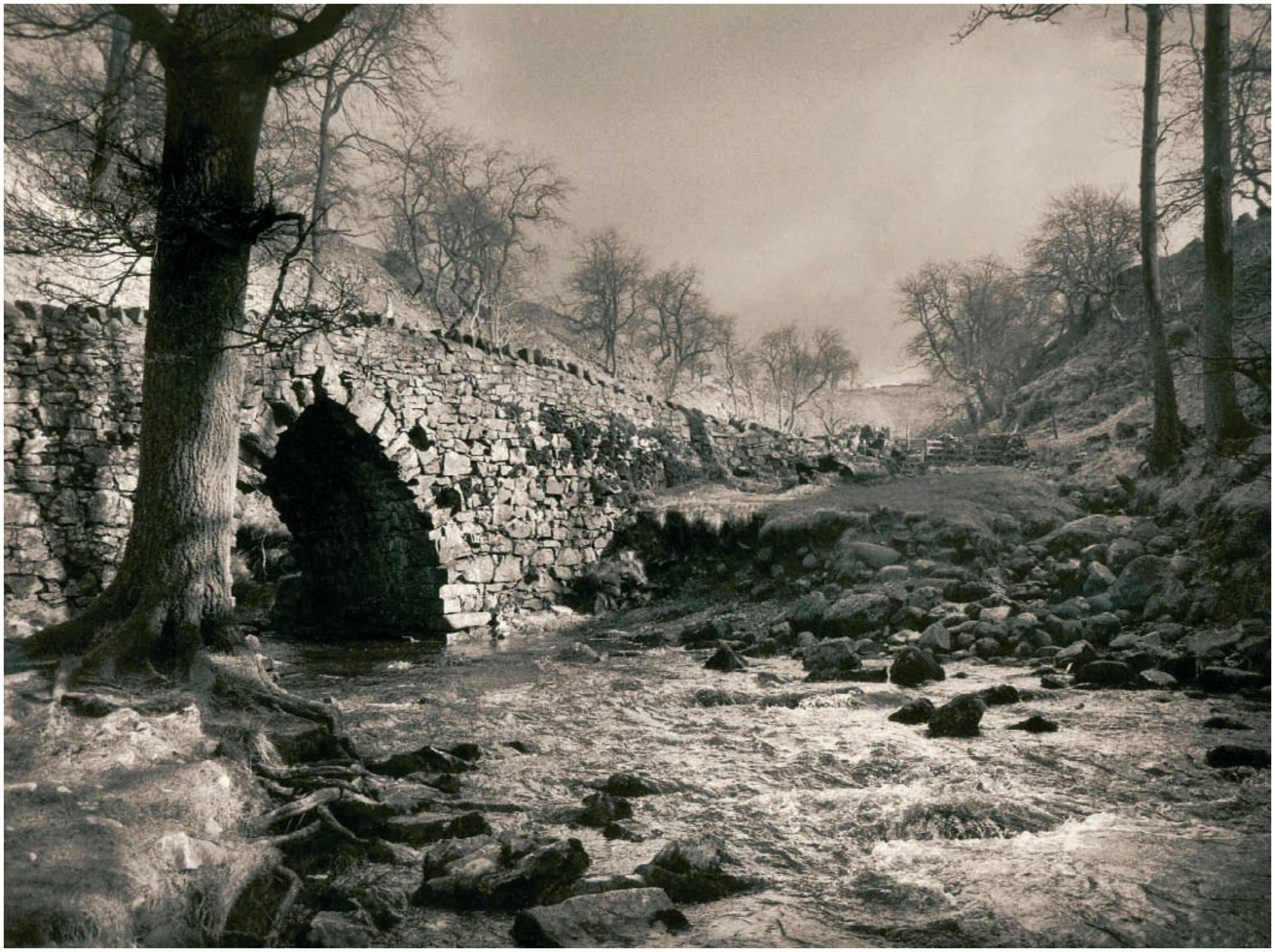

+2 1/2 filter 00
+1 filter 5
+3 1/3 filter 00 but dodged during 2nd exposure
base exposure
1st 2.1s filter 00
2nd 8.5s filter 5
-1/3 during 2nd exposure
+2 1/2 filter 00
+2 1/2 filter 00
+2 1/2 filter 00
-1 during 1st exposure

fig.5 (left) This is the printing map for the final print, showing highlight and shadow dodging during the split-grade exposures and burn-in exposures for sky and edges.

fig.6 (below) Final print, exposure as fig.4, but with additional dodging during filter-5 exposure around gate, additional 2 1/2-stop filter-00 exposure for each edge and some added exposure to tree trunks. Finally, the print was lightly bleached and toned in variable sepia toner.



# Corkscrews

## Considerations for reflective objects

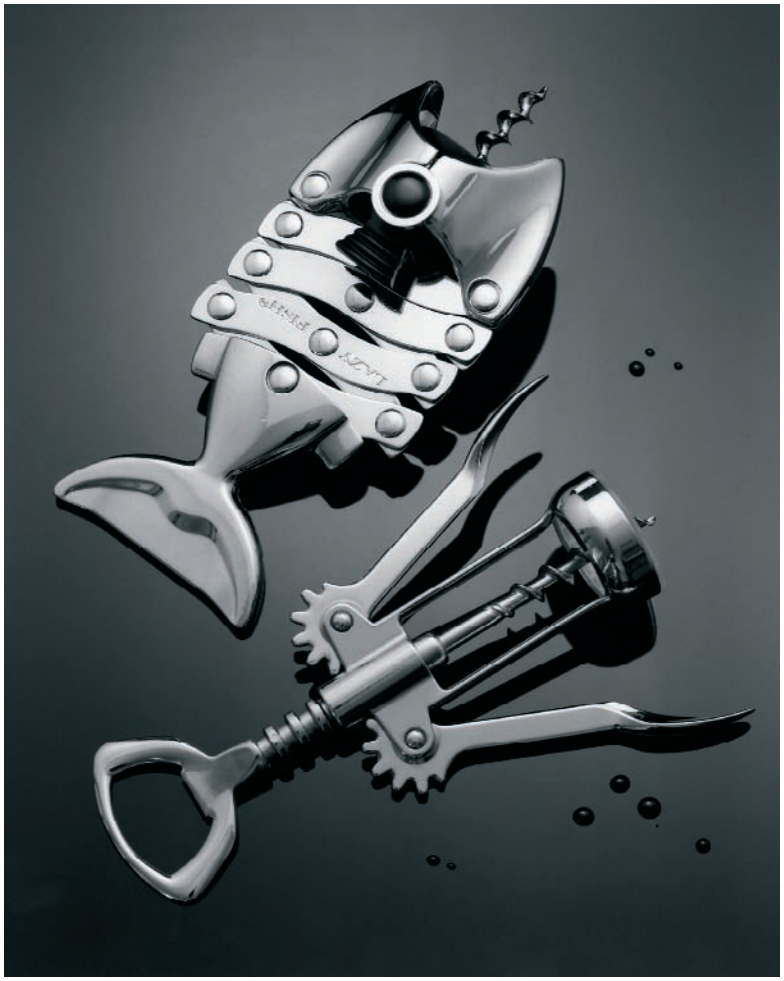


fig.1 This shows the final image, printed for sufficient tone and detail in the 'ribs' of the corkscrew and yet still showing adequate detail in the black plastic boss. This enables good midtone contrast but lets deep shadows and specular highlights reach Dmax and paper white. The exposure was changed to 9.7 seconds with filter 1/2.

Photographing and printing shiny objects present unique problems that the landscape and natural history photographer rarely encounter. With most images of natural subjects, we consider the reflectivity of the objects and their relative illumination to determine exposure, development and printing. Although the subject brightness range may be high, it is normally possible to expose and print an image with a literal rendering on paper within a reflection density range of 2.0.

Luckily, extreme subject brightness ranges are uncommon since we rarely include God's light source directly in the final image. The exceptions are mostly sunsets and reflections off water for which, in most cases, the subject brightness range and, more significantly, the expected image treatment do not give rise to tonal compression problems. In fact, if one were to include the sun in an image it would show up the limitation of optics and emulsion alike, with lens and film flare as well as the possibility of the sun's image becoming a dark circle in the printed image.

### Problems

Clearly, the most obvious problem with photographing reflective subjects is the treatment of the bright highlights, caused by reflections of the incident light source. In addition, reflective objects can also reflect areas that have little illumination, creating a dark abyss and compounding the subject brightness range problem. Lastly, as is often the case with still life, the object will also show unwanted reflections of the object surroundings, picking up cameras, tripods, clothing and so on. For this case study, we shall consider the problems with film exposure and printing options for these reflective or 'specular' highlights and leave the logistic considerations of still life setup for another time.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50052-1

## Picture Setup

In fig.2 we have the still life setup for two chromed corkscrews placed on black plastic, often known as Perspex or Plexiglas. This image is made entirely of reflective surfaces, apart from the black plastic bush on the fish-shaped corkscrew. The Perspex is surrounded on three sides by 2 x 2 feet, 1 inch thick polystyrene sheet, painted black on the inside and topped with a large diffuser made of white plastic. Lighting comes from a single domestic 100-watt tungsten spot lamp mounted above the setup and aimed towards the middle of the diffuser. The hot spot on the diffuser creates a natural lighting gradation over the black plastic background. The camera was a Fuji GX680 with the multi-format back set to 6 x 8 cm and loaded with Ilford Delta 100 film. The 4.5/150 mm lens was set to f/8. A high viewpoint and a small degree of lens tilt were applied to ensure sharpness throughout the image. With the help of a small homemade lookup table, it was determined that 2/3-stop additional exposure were required to compensate for the lens extension.

## Metering Considerations

Metering this still life presents a number of issues. When you meter a subject with natural surfaces, it is natural to stand somewhere alongside the camera and take the measurements. For these subjects this approach is perfectly adequate, but accurate readings of reflective surfaces demand measurements along the lens axis. With reflective objects, we are really metering the diffuser surface illumination, via different reflective surfaces. If we were to meter liberally from the side, the meter would potentially pick up a different part of the diffuser's surface and give a wrong exposure indication. In this setup, it was impossible to get very close to the lens axis, because the Fuji is a big brute. Therefore, I had to remove it from the tripod so that I could place the spotmeter in its place.

The second metering issue concerns the shadow exposure. Exposing for the shadows is tricky, since they only appear as empty voids on the black plastic. They showed no detail in the viewfinder, even when a small fill in reflector was used from the front. In a final print, these would be dense black, so instead it makes pictorial sense to meter the black plastic bush, which shows some texture and detail, place it on Zone II and let the cast shadows become empty clear film.

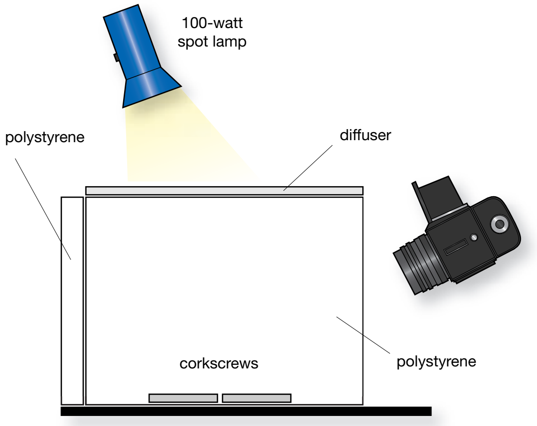


fig.2 This is the still life studio setup showing overhead diffuser, reflectors and lighting.

The third practical metering issue with this subject is that the image has many small shadow and highlight areas, too small for a 1° spotmeter to work effectively. Normally the optics in a spot meter are designed for a minimum distance of 1 meter. Used closer than this, the image loses focus in the viewfinder and on the sensor and the preciseness of the measuring area is lost. To make the best of the situation, I moved in closer along the lens axis and

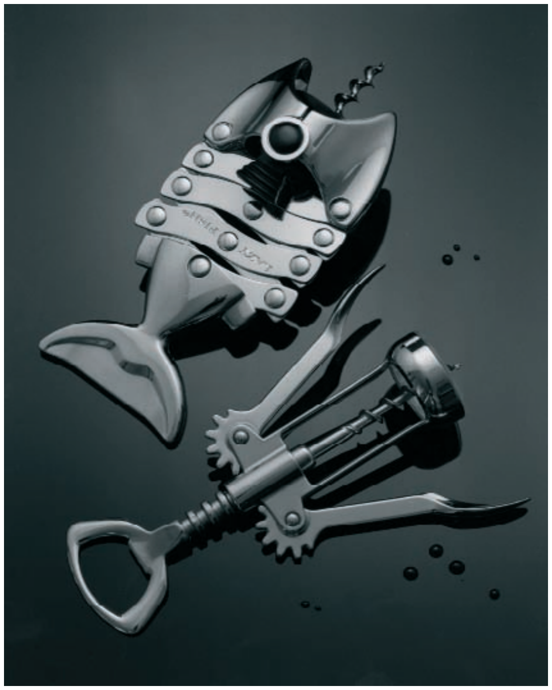


fig.3 This is an 'automatic' print, using the full density range of the negative from 0.04 to 1.80. It was printed for 14 seconds with Ilford filter 00 on Agfa Multicontrast Premium paper.

placed strips of black cloth over the bright metal parts of the 'fish' to avoid nearby highlights influencing the shadow reading. Even so, with this image, I took the precaution of making a Polaroid to check everything was in order.

Last but not least, our fourth dilemma is highlight choice and zone placement. The temptation is to meter the brightest highlight in the image on the lower corkscrew. The chrome surface is reflecting the brightest part of the illuminating diffuser and is a true specular highlight. If we desired this to translate to a Zone VIII highlight on a normal grade paper, it would require less development (N-) to reduce the negative density range and risk compressing the vital midtones of the printed image. An alternative is to meter the bright ribs of the 'fish'. A meter reading here is at least two EVs lower than the specular highlight, a subject brightness range now within the range of normal development. The metal here has a slight tint and a textured surface, making it immediately more suitable for visualizing as a print Zone VIII, with the extreme highlights beyond Zone IX. The key is to meter the key parts of the image, in this case the texture extremes of the subject, aiming the spotmeter at the ribs and the black plastic boss. The specular highlights are Zone IX or higher. They will be paper-white in the print.

The metered exposure was 4 seconds at f/8. Allowing for film reciprocity failure, the final exposure was set to 8 seconds. A monochrome Polaroid picture was used to check the exposure and annoying in-focus reflections at the taking aperture.

## Print Visualization

The same zone placement dilemma occurs at the printing stage. If we use the entire tonal scale of the subject and translate these into print values between II and VIII, avoiding dense blacks and bright whites, the interesting midtones are compressed and the result is dull. This is printed just so in fig.3 with the specular highlight on the corkscrew placed on Zone VIII.

If we consider the texture range of the subject, using the ribs and the black boss as the key elements and print these for Zone VIII and II then the midtones have more local contrast, and the print has a greater dynamic impact, as shown in fig. 1. In this print, the ribs of the 'fish' have a reflection density of 0.04, the small highlight on the lower corkscrew is paper white and the shadows under the corkscrew have a reflection density of 2.2. This print shows better detail in the black plastic and an overall sparkle that sets it apart. Further improvements for commercial purposes might also require an emphasis of the 'lazy fish' logo. This might be accomplished by applying a localized burn-in exposure at a high-contrast setting, or with filter 5, to pick up the black edges of the embossed letters, without adding appreciable density to the rest of the ribs.

# Portrait Studio Lighting

## Fundamental lighting setup to illuminate beautiful faces

The purpose of a portrait photograph is to create a representative image of a person. The task can be as simple as capturing a mirror-like image, clearly identifying the person, as is needed for a passport, for example. Or, it can be as complex as having to portrait and express an individual's personality as part of the picture. Creating both images is made easier with a fundamental understanding of how different lights are effectively used to illuminate model and background.

### Studio Lights

In a typical portrait studio, we differentiate between five different sources of illumination to provide the most suitable lighting for people photography: key light, fill light, rim light, backlight and 'kickers'.

**Key Light**: The key light is the main source of illumination and is normally the strongest and largest light, casting harsh shadows. Common equipment for this light is a small soft box, an umbrella, a diffused reflector or a so-called 'beauty dish'.

**Fill Light**: The fill light reduces the deep, strong shadows created by the key light. This light is often a large soft box or umbrella set to 1/4 of the key-light strength, but a large reflector may be all that is needed to sufficiently illuminate key-light shadows.

**Rim Light**: One or more small but strong reflectors from the back create a rim of light on hair and clothing, which separates the model from the background and enhances the illusion of three dimensions.

**Backlight**: The backlight separates a dark subject area from a dark background by illuminating the background directly behind the subject with a small reflector of low to medium power.

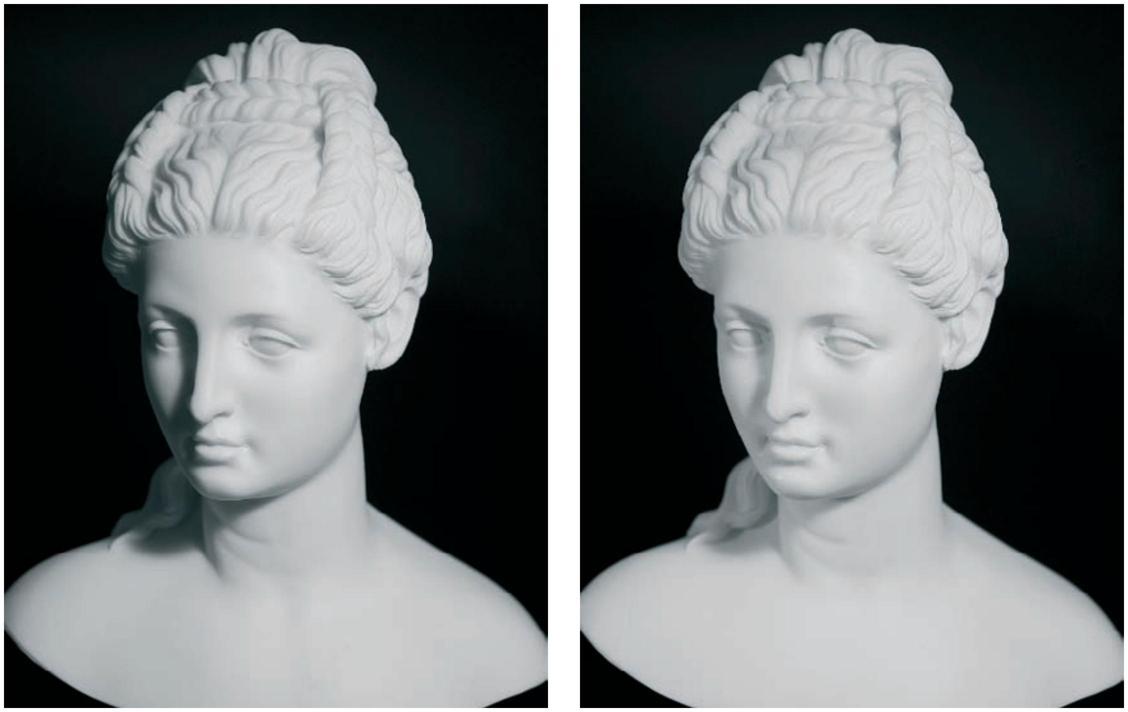
**Kicker**: Kickers are small spotlight reflectors at various power settings, which are used to highlight important subject areas or to keep supporting shadow areas from disappearing into total darkness.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50053-3

fig.1 Starting with the key light and then adding the other light sources one by one slowly builds up the standard three-point lighting setup, used for this classic three-quarter portrait.

a) The **key light** is the main source of illumination. A diffused reflector provides a sufficient amount of light from above the model to illuminate one side of the face, while casting undesirable shadows onto the other.

b) A large **fill light** throws light into the shadows, cast by the key light, without eliminating them. A soft box, set to 1/2 or 1/4 of the key-light's power, illuminates the dark side of the face without adding intolerable shadows of its own.

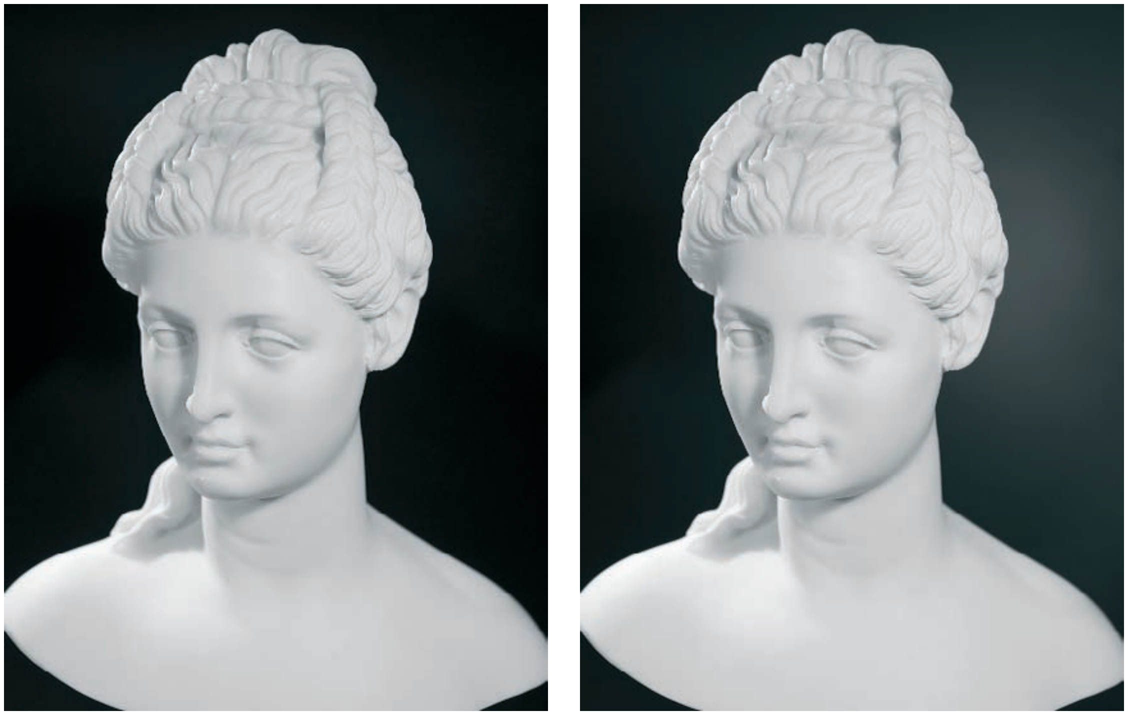


a) key light

b) key and fill light

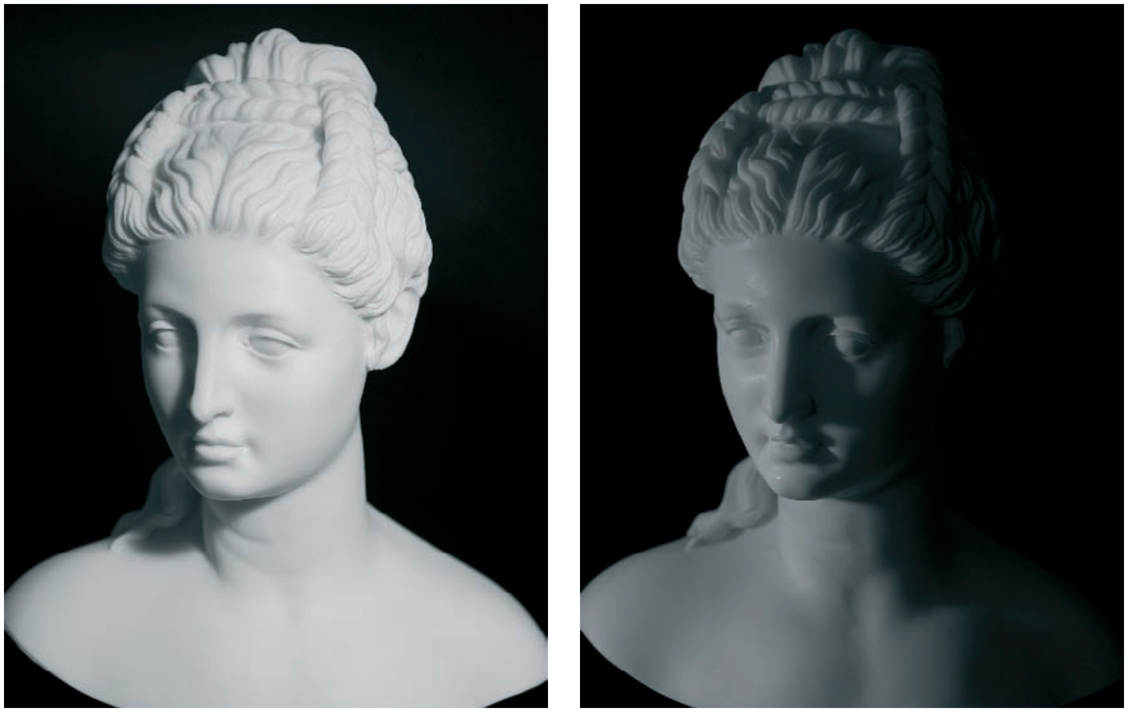
c) Pointing a small but strong reflector at the back of the model's shadow-side creates a seam of light, or **rim light**, lifting it from the background, while adding brilliance to the picture and enhancing the illusion of a three-dimensional image.

d) A low-power **backlight**, selectively illuminating the background behind the model, adds interest and depth to the image. This light finds more application with dark-haired models against a dark background.



c) key, fill and rim light

d) key, fill, rim and backlight



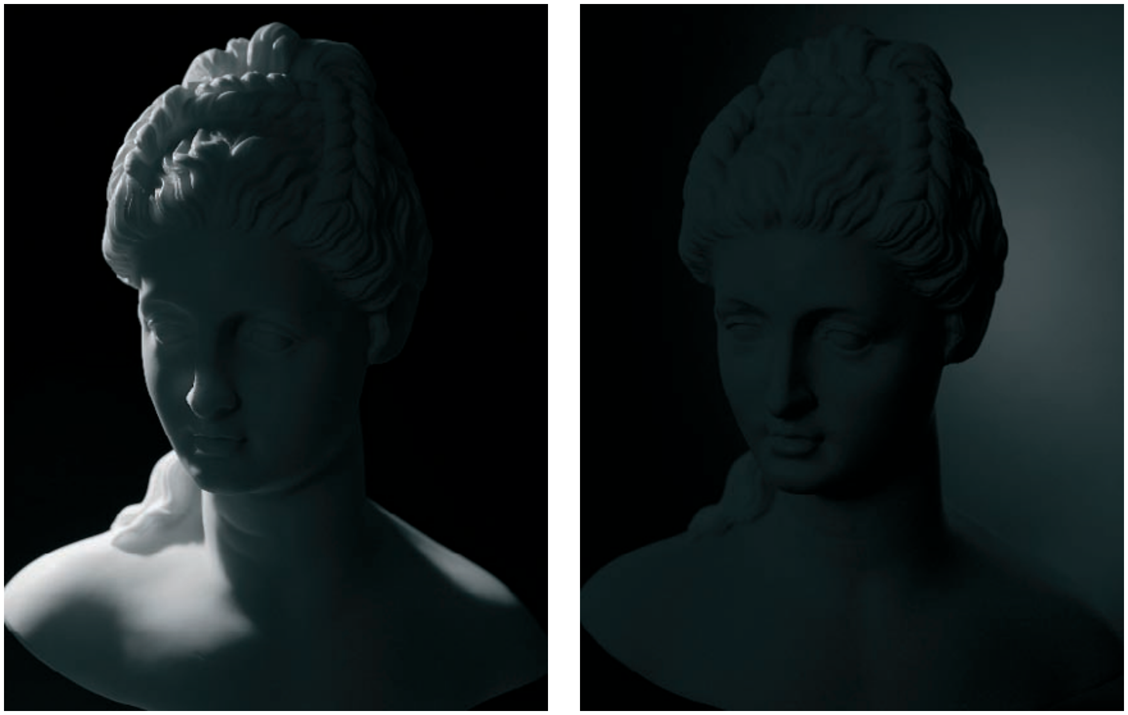
a) key light

b) fill light

fig.2 Evaluating the four lights separately illustrates their individual contribution to the overall effect.

a) In this three-quarter portrait, the **key light** provides contrast and highlights the structure of the entire face without over-emphasizing skin imperfections. Start by positioning the key light 45° to your right and well above the model’s head.

b) The **fill light** is the soft opposite of the key light. Start by positioning it to your left and slightly above the model’s eyes. To reduce the shadows cast by the fill light, move it closer to the camera or use a large reflector.



c) rim light

d) backlight

c) Using a **rim light** is similar to taking outdoor photographs against the sun. Start by positioning it as far and high as possible, and point it at the model’s hair. Adjust until the model’s contour is accentuated by a seam of light. Watch for disturbing hot spots on cheek and nose.

d) The **backlight** is optional in this setup but helps to separate dark subject areas from dark backgrounds. Start by positioning it at the same height as the model’s head, and point it at the background behind the shadow-side of the model’s hair.

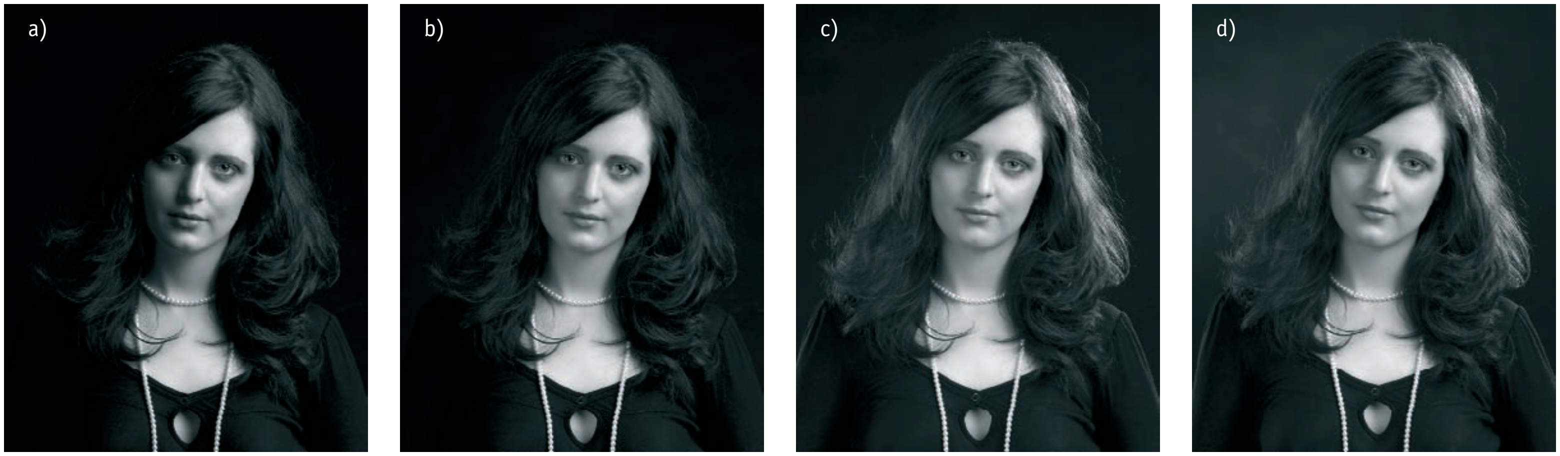


fig.3 A dark-haired model, wearing dark clothes in front of a dark backdrop, can easily blend into the background, but three-point lighting can help to master this challenge by clearly separating all dark subject areas from each other.

## Three-Point Lighting

Many different and effective lighting setups for portrait photography are practiced. Nevertheless, it is sensible to start with three-point lighting (fig.4), which is easy to set up and provides the opportunity to explore more creative settings from there.

Most full-face portraits are taken with the head in a three-quarter position (see fig.1). When deciding which side of the face to feature, keep in mind that many people have a dominant eye, which is more open and appears bigger than the other. This difference is minimized if the less dominant eye is the closest to the camera. Positioning the key light on the same side as the visible ear is referred to as 'broad lighting'. If it is placed on the opposite side, we refer to it as 'short lighting'. To choose between the two, one should always consider the features of the subject to be photographed. Short lighting makes a full face appear thinner and further minimizes the appearance of differently sized eyes. Broad lighting complements a thinner face and avoids potential reflections in eyeglasses. However, a single, small catchlight reflection in each eye itself is welcome, because it adds a spark of life to the subject (fig.3a).

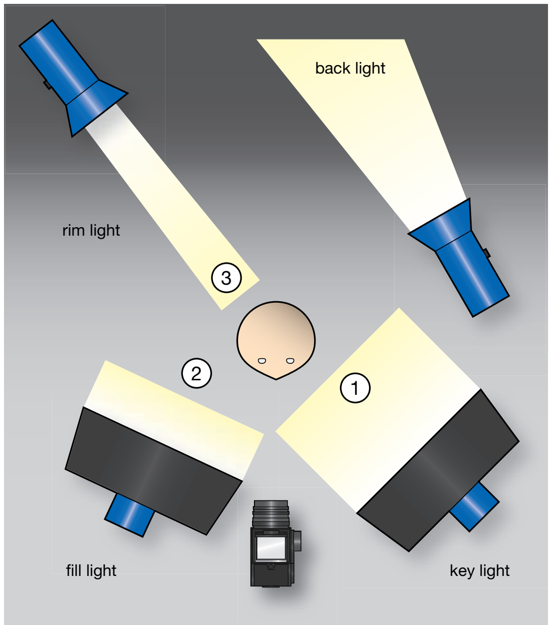


fig.4 A three-point lighting setup is the ideal starting point for a frontal or classic three-quarter portrait, but it is also an effective way of providing successful lighting for product and table-top photography.

The purpose of the fill light is to add detail to the shadows cast by the key light (fig.3b). This reduces the overall subject contrast and ensures that skin imperfections are not exaggerated. Selecting the largest fill light available and keeping it slightly above the model's eyes, close to the camera, prevents it from creating disturbing shadows itself. The amount of fill required depends on the subject and the desired effect. Typical lighting ratios between key and fill light range from 2:1 to 4:1. Too small and too strong of a fill light may add extra catchlights to the eyes, which most photographers find objectionable.

Rim and hair lights are used to illuminate the edges of the subject and produce a separate highlight, setting dark hair and clothing apart from the background (fig.3c). A rim light is usually placed behind the subject and opposite to the key light, but hair lights can be anywhere behind the model. Nothing supports the illusion of three dimensions more than strategically positioned rim and hair lights.

An optional backlight, pointed at the background (fig.3d), surrounds the subject with a pleasing glow and helps to set its shadow areas apart from a dark background. Small additional spotlights, so-called kickers, can be used to add illumination to any part of the scene. Beyond these fundamental instructions, perfect lighting is not a mechanical textbook exercise but requires experience, patience, creativity and the willingness to experiment.

# Ingatestone Hall

## Lime walk, a study in infrared

For many years, I was unaware of the creative effects of infrared film. It was only when I began to see the now familiar eerie images in photographic journals that I started to take note. Ironically, in the early days when I was restricted to 35 mm, grain was the target of my condemnation. I can remember swapping films and developers almost weekly trying to find the combination that made my results smooth. Now, the coarseness of the image was part of the aim.

### Nature or Nurture

Confronted with a variety of pictorial scenes, the photographer has a couple of choices, either 1) to apply a standard style or 2) to choose from a variety of materials and techniques to complement the scene. In recent years, I would walk about the grounds of historic buildings, the regimented rose beds and the ghastly light gravel paths, without a firing a shot. In this instance walking around the Tudor edifices at Ingatestone Hall in England, with its mellow brickwork and rampant wisteria, Kodak High Speed Infrared (HIE) complemented the autumn scene and rescued the day.

Kodak HIE must be loaded and unloaded in complete darkness. The clear base of the film, which has no antihalation layer, acts like a fiber optic and beams light along its length. If even the tip of the film leader were exposed to light, the light would beam back into the cassette and ruin the entire film. The film instructions suggest 1/125 s at f/11 with a red filter as a starting point. I pre-loaded the Leica R6 and 24mm lens and attached the go-everywhere mini-tripod to the base plate.

The user of infrared film has a number of filter options to choose from before actual picture taking can occur. Infrared films not only see shortwave infrared, but also the visible spectrum. This broad spectral sensitivity allows the photographer to mount a number of different filters, mostly oranges, reds and dark reds, to alter the relative proportion of visible and invisible light reaching the film. Changing the relative strengths of infrared and visible light changes the tonal rendition of different materials, as well as the effective speed of the emulsion. In this instance, I chose the common 25A red filter for a balance of effects.

### Metering and Contrast

Metering is a rather unpredictable affair with infrared film. Generally speaking, one does not bother. Camera and handheld meters do not have the same color

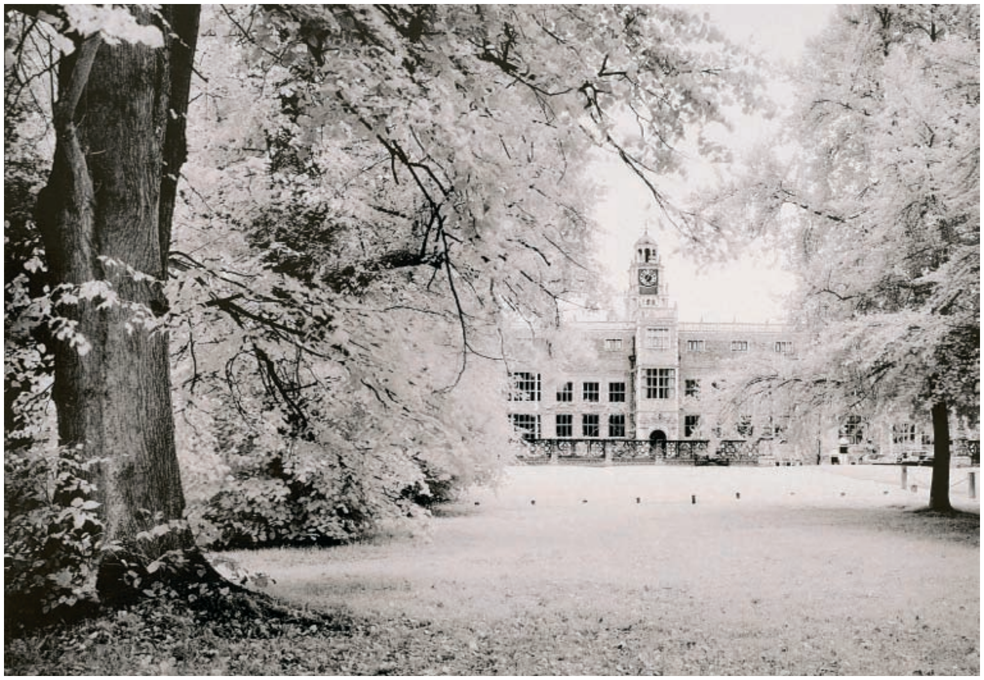


fig.1 Ingatestone Hall in Essex, England, Kodak HIE, Leica R6, 24 mm, 25A filter, lith print, selenium toned

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50054-5

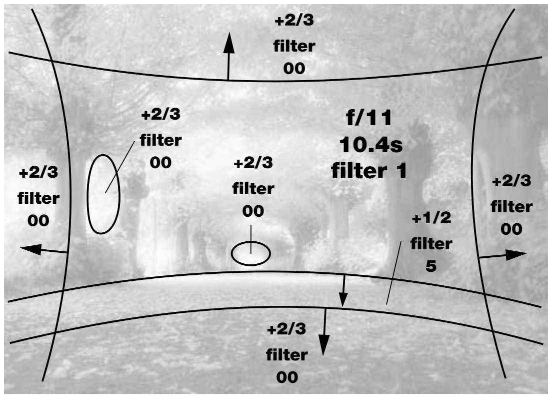


fig.2 This is the printing map to prepare the final image. The burn-in exposures are in f/stops and referenced to the base exposure time.

sensitivity as film, and so would give entirely false readings. Instead, many users follow the instructions supplied with the film, which gives exposure recommendations for different daylight conditions. In this instance, I remained undecided with my classification of the lighting conditions, so made a mental note to bracket my exposures. Prior experience had shown that a range of exposures produces a variety of images, from low-contrast grainy effects, to high-contrast images with less obtrusive grain.

By chance, the wonderful long tonal range of HIE gives the user the ability to alter the contrast of the negative, by changing the exposure. As the exposure is increased, not only does the shadow detail build up, but also the overall negative contrast is reduced. Infrared negatives can become exceedingly dense, so dense, in fact, that images virtually disappear into darkness, only to resurface evocatively on the print with a long exposure and filter 5.

Back in the grounds, the autumn damp chill had not yet descended over Britain. Only a few sharp frosts had started the leaves on their earthly descent. The gardens extend at the back of the house, dominated by a plain rectangular stew pond, used to provide the house of old with fresh fish and freshwater mussels. Along one long side is an elegant avenue of lime trees, with a two level coppice in the traditional style. The willowy branches formed an ethereal canopy overhead, backlit by the weak autumn sun. This was the perfect hunting ground for infrared film, sun, foliage and earth.

A low viewpoint emphasized the glorious leafy canopy. The fallen leaves broke up the dark path nicely, but they needed to be sharp. An aperture of f/16 was set on the 24 mm lens with the hyperfocal distance set to f/11 to extend the focus throughout the picture. The miniature tripod sat on its six-inch legs, and the self-timer ensured a vibration free shutter trip. Since the image was in shade, a series of bracketed exposures centered on the film carton setting, 1.5 stops apart, ensured at least one good negative.

## Development

Back in the darkroom, I knew that this Kodak film had a grain attitude. I had to decide whether to emphasize or mask it. As it happens, my choice of developer was influenced more by the available development information. Contrary to my own recommendation, I had not performed any exacting development test with my preferred developer, and so I relied upon the published times for Kodak developers. Since my then standard developer, Ilford Ilfotec HC, was similar to Kodak's HC110, I estimated the times to be equivalent. The film was developed for 7 minutes at 24°C, with an initial 30 seconds of continuous inversion, followed by vigorous tank inversions every 30 seconds punctuated by tank tapping to avoid air bells and streaking. The negatives were fine, with the bracketed sequences covering a wide span of density and contrast.

## Printing

After contact printing the film through filter 1, the best looking image of the sequence was chosen for printing. This image showed sufficient shadow detail and good separation of the midtones. A straight print was made on 8x10-inch Agfa Multicontrast Premium paper through filter 1 for 10.4 seconds, which I judged to give a pleasing contrast in the main area of the trunks and leaves.

The test print, not shown, had several problems with this exposure setting. The sunlit leaves on the far left were too light, as was the gate in the distance. In addition, the foreground ground and leaves were weak and needed some bite. The printing map, fig.2, shows the final solution. After the main exposure, with the aid of a punctured burning card, a further exposure of 2/3 stop with filter 00 was applied to the gate and leaves between the tree trunks on the left. The bright highlights at the edge of the print were suppressed by additional exposure at a soft grade. This was accomplished with four 2/3-stop filter-00 burn-in exposures,

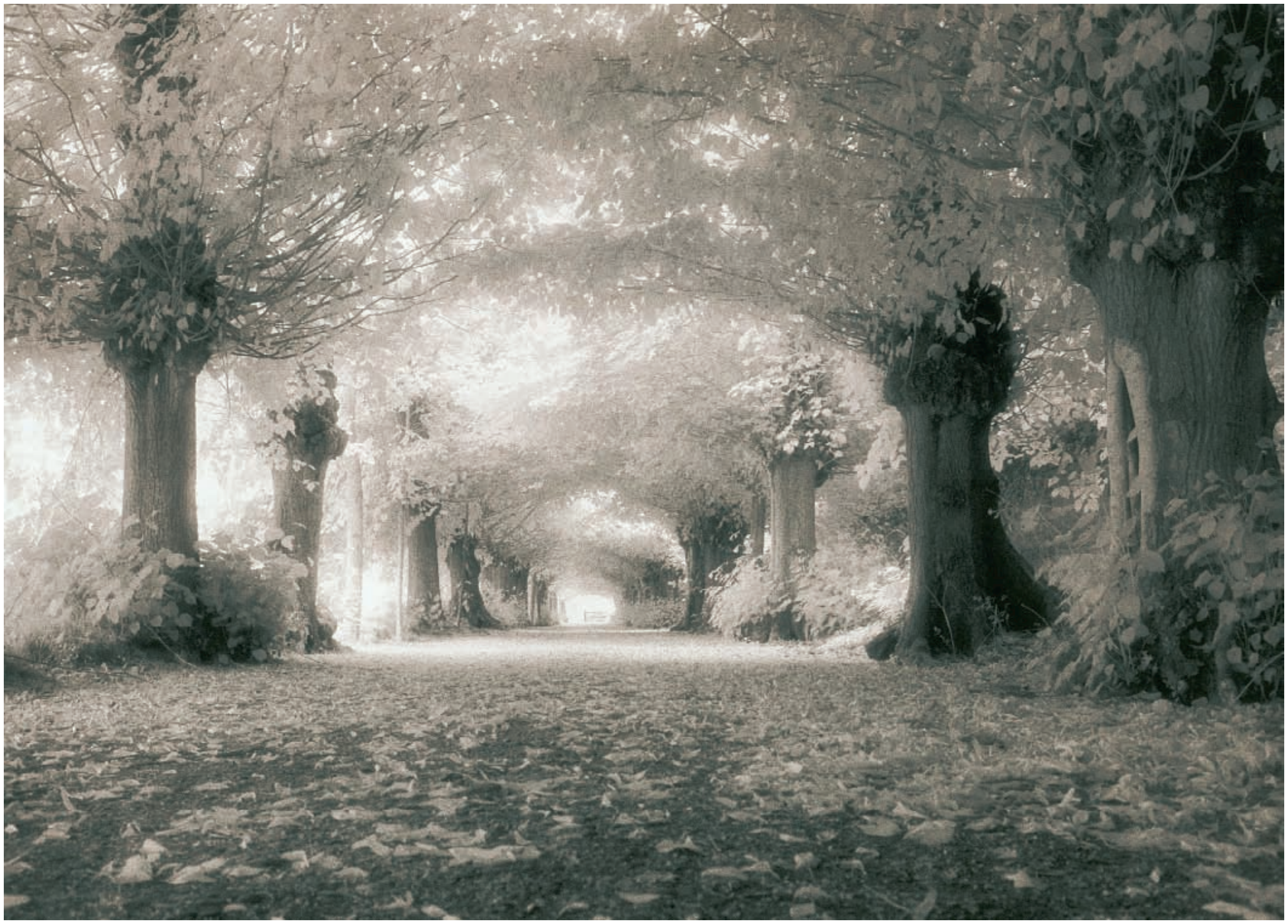


fig.3 Lime Walk, Ingatestone Hall, Leica R6, 24 mm 1/30 s, f/16, printed according to the printing map in fig.2, Agfa Multicontrast Premium

using a floppy card for a mask. Lastly, the foreground was emphasized with another 1/2-stop filter-5 burn-in exposure. It is easy to leave telltale marks with a high-contrast burn-in, so the mask used for this exposure was kept on the move and rippled to avoid any possible telltale signs of its application.

The final print is shown in fig.3. In order to achieve the desired image color, the print was bleached and toned using a variable, odorless, sepia toner. The benefit of variable sepia toners is that the image color can be fine-tuned from a warm to a cool brown by altering the proportions in the toning solution mix.

This particular scene has a peaceful, painterly quality, which suggests a number of diverse print interpretations. Over the years, the image has been lith printed and the prints selenium toned, as well as sepia toned, and combination toned in sepia and gold. In addition, I have printed a successful high-key version with a low-contrast, overexposed negative on the roll.

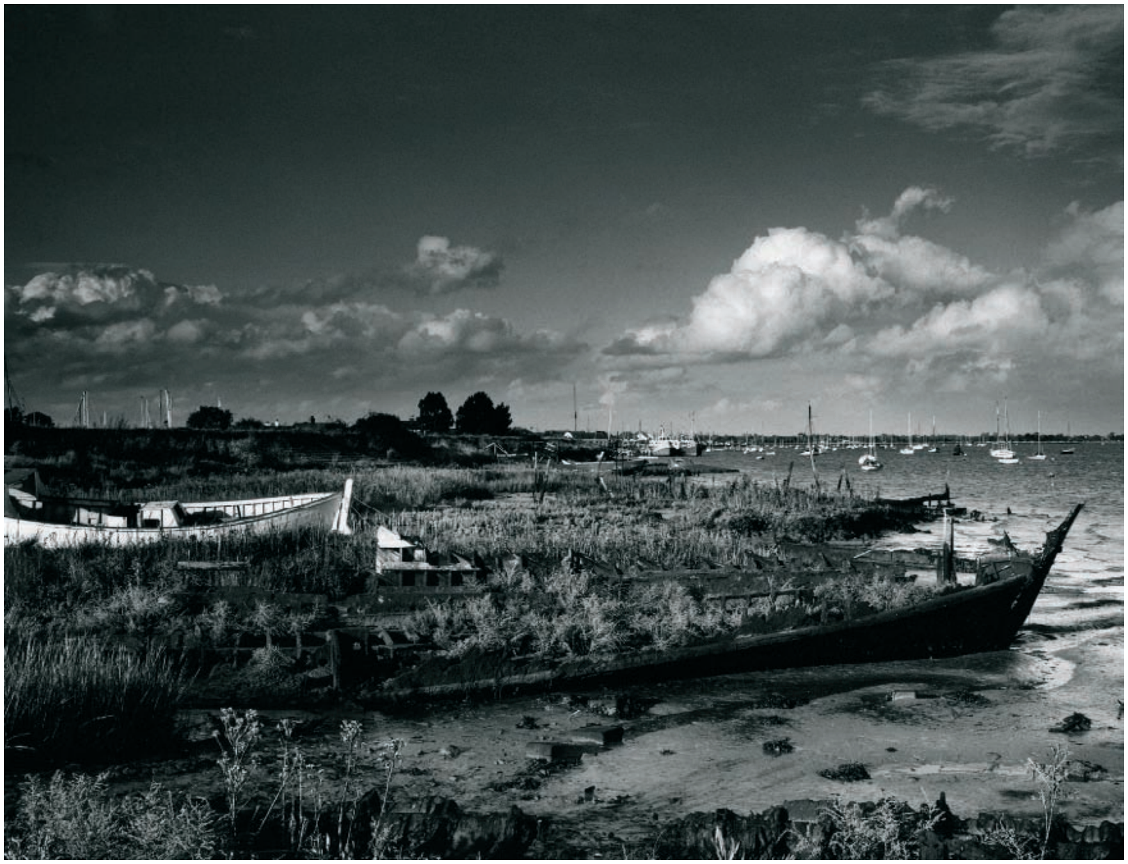
It is important to note that, even at a modest enlargement, the grain in infrared film is well defined, very obvious and easily draws attention to itself. Therefore, the larger the print, the more important it is to achieve overall grain sharpness. In doing so, it is essential to select the optimum aperture of the enlarging lens and to double-check each corner for critical sharpness with a grain focuser. As well as precisely aligning the enlarger and easel, one should use a glass negative carrier with an anti-Newton glass on top, to ensure the film is flat, and consequently, focus is pinpoint sharp throughout.

# Heybridge

## A low-contrast subject on a high-contrast day

The Heybridge Basin is near the town of Maldon in Essex, England on the River Blackwater where it meets the Thames estuary. Maldon was an important marine town until transport by road became more economical than transport by water. Until the early 20th century, sailboats transported hay bales, brought from the fields of Essex, to the city of London. There, the hay was needed for horses, still a main mode of transportation.

The old boats have long since been replaced by modern marine vessels, used by wealthy weekend yachtsmen for entertainment, but some of the old boats remain and are maintained by a few enthusiasts. The ones beyond repair have been left neglected on the river bank exposed to the elements, and the constant movement of the tide allowed them to sink slowly into the mud where they silently rot.



© 2001 by Don Clayden, all rights reserved

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50055-7

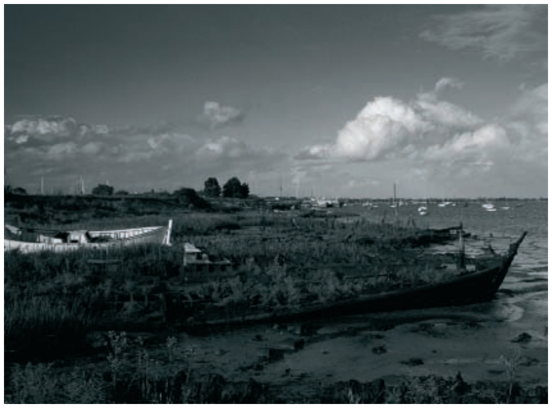


fig.1 With a darkroom meter, the bright cloud and the bow of the dark ship were measured to estimate exposure and negative contrast. The image was printed on Ilford Multigrade IV RC, grade 0.5 and exposed at f/11 for 42.7 seconds. The result was disappointing and did not reflect the light and mood of the original scene.

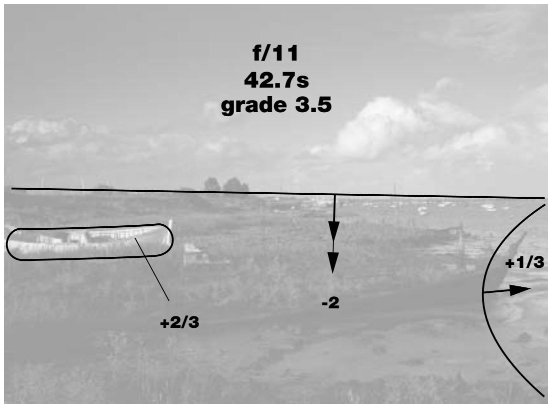


fig.2 The image is treated in two sections. The bottom was dodged, improving the dark foreground, but underexposing the white boat and the water to the right of the boat. These were burned-in with a selective exposure through a constantly moving hole in the burn-in card.

This photograph was taken on a sunny Sunday afternoon in November 2001 by Don Clayden. He used Delta 100 in a Mamyia 7 with a 65mm lens to capture the image. The film was rated at EI-80, exposed for 1/15 s at f/22 using a polarizer and developed in ID-11, 1+1, for 9 min at 20°C.

Don had printed the image according to the measurements taken with his darkroom exposure meter, selecting the bright cloud to determine the exposure time and the bow of the dark ship to estimate the required paper grade. The resulting image, fig.1, was printed on Ilford Multigrade IV RC, grade 0.5 and exposed at f/11 for 42.7 seconds. The print was far from what Don had hoped for, and he was disappointed. He showed me the print, and we decided to give this another try.

The negative showed only faint density in the foreground, but the clouds and the white boat were rendered extremely dense. It would have been far better to have given more exposure and less development, but it was too late for that. We used my darkroom meter, to measure the same negative areas Don had selected and came up with a very similar result. The high overall contrast of the negative demanded this low paper grade. The meter had not malfunctioned, we just did not use it appropriately for this image. The overall negative contrast was very high (white cloud - dark bow), but the local contrast (foreground - dark bow) was relatively low. In cases like this, the local contrast areas have to be dealt with separately. An overall contrast evaluation, as we attempted, will always yield a print that looks too soft.

Determined for success, we treated the image in two sections, one above the horizon and one below. For the top section, there was no need to modify the base exposure, as we liked the tonality and detail of the white cloud. For the bottom section, the exposure was reduced, and the paper grade was raised until the foreground had enough contrast to reveal its detail. Electronic exposure meters are capable of performing selective image evaluations without further test exposures, but the task can also be completed using one or more simple test strips.

The final image, fig.2, was printed again on Ilford Multigrade IV RC, although the paper contrast was raised to grade 3.5, while the base exposure was kept at f/11 for 42.7 seconds. The bottom section was covered up (dodged) after one quarter of the time (-2 stops). This improved the dark foreground as a whole, but the white boat and the water at the right suffered from underexposure. Additional exposure through a hole in the burn-in card compensated for this local lack of density. The final image looks sharper and comes much closer to representing the original light on that sunny Sunday afternoon.

# Karen

## An example in print manipulation

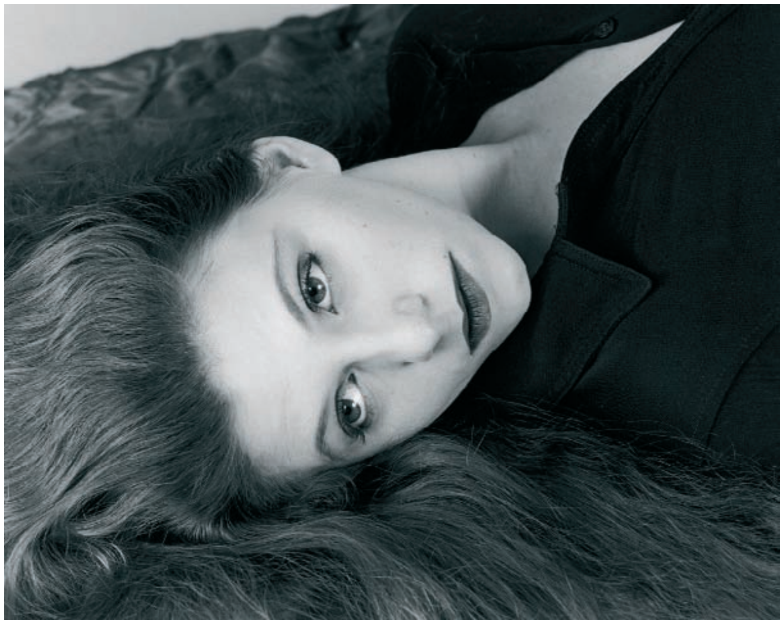


fig.1 (above) This is a straight print exposed for 6 seconds with filter 2.

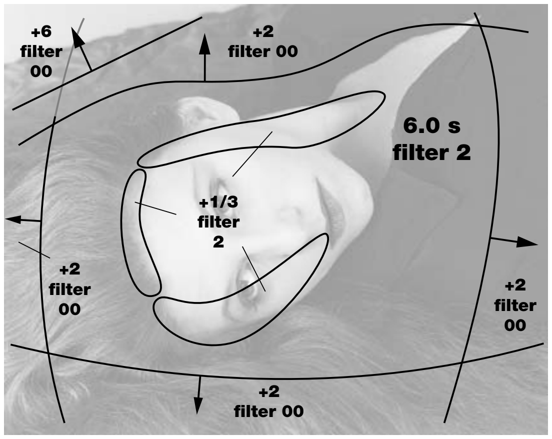


fig.2 (right) The printing map for the final print records all edge-burns and modelling burn-ins.

Occasionally, in the heat of the moment, one forgets the golden rules of composition. These rules, as applied to the image in the viewfinder, include scouting around the main subject for distractions and omissions. These distractions can often seem harmless enough at full aperture but zap into focus on the negative, complicating matters further. A recent studio session with an amateur model proved to be just such an occasion.

I was happily shooting away with a Mamiya RB67 Pro SD, 645 back and the superb 140mm f/4.5 macro lens, mesmerized by Karen's glorious hair and eyes. My favorite image from the shoot, taken at an unusual angle, has two big problems. A straight print, illustrated in fig.1, clearly shows that a shortfall in the satin backdrop as well as the flowing hair highlights are competing for attention with the face, drawing the viewer's eye out of the print.

### Printing

In fig.1, the print shows good shadow detail, for example in the weave of the black blouse. The dark hair shows plenty of sharp detail, too much in fact, and with this exposure, the face is a little bland and shows little modelling. To remedy the situation, the main 6-second filter-2 exposure is supported by burn-in exposures along each side, using filter 00. For these a piece of flexible red card was used with a sweeping motion to fade the effect. The shape of the card was carefully chosen to follow the natural lines in the image. This suppresses the hair detail at the print boundaries and places more emphasis on the face. These burn-in exposures, however, were not enough to eliminate the bright top left corner. A test strip, (not shown), indicated a further 6 stops were required to render the corner black.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50056-9

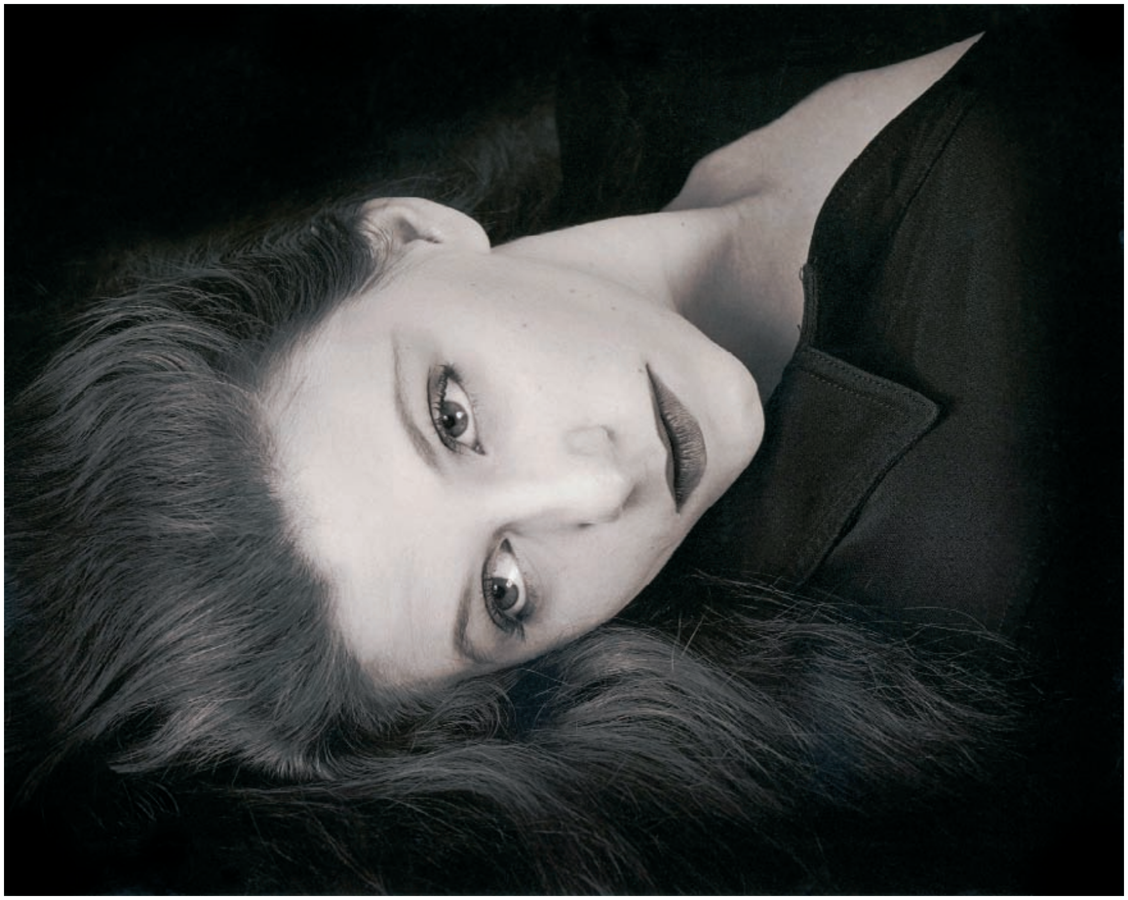


fig.3 This is the final print. It was exposed according to the printing map in fig.2. The top left corner was given 6 stops with filter 00, and the cheek and neck received 1/3 stop with filter 2. Finally, the print was selenium toned, lightly bleached and sepia toned.

For this corner, I chose to use a straightforward burn-in with the negative in place, rather than a flash exposure, for two reasons. 1) The main exposure was fleetingly short, so I could use a sensible burn-in time. 2) It would be difficult to control the flash exposure to just the required area without using a fixture to hold the card in the right area. In the end, I opened up by 2 stops on the enlarging lens and burned-in the corner using filter 00 with the help of a card mask for the same time as the edge-burns.

I did try using a flash exposure to suppress this corner on another print, with similar results, and would recommend this approach for tired arms and when the burn-in time is over 2 minutes. If a flash exposure is tried, it is good practice to protect the print from stray light, which finds its way around the mask. This is accomplished with a piece of black cloth over the required area. During the flash exposure, the mask is moved to avoid telltale signs in the print, fading the effect up to the boundary of the black cloth.

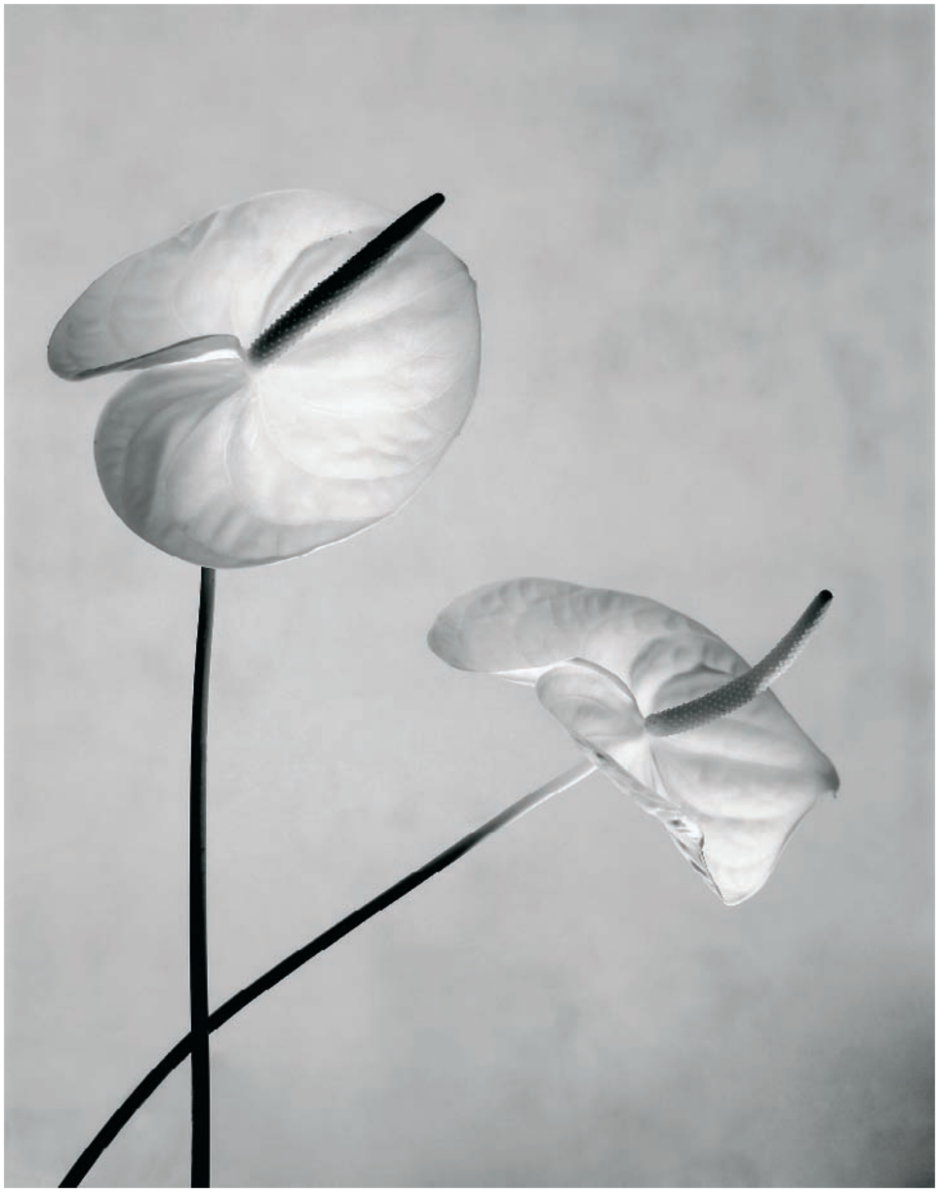
In the final print, fig.3, in addition to the suppression of the print corner, the face has some additional modelling created with an additional exposure to the cheek, forehead and neck. This exposure was made using filter 2 using a mask with a small crescent hole. As usual, the card was kept on the move to ensure no telltale marks were made in the print. The print was toned fully in selenium, followed by a light bleach and sepia toning to warm the image.

The negative of this print is a reminder to check the viewfinder more thoroughly. Fortunately, in this case a striking portrait has been retrieved with a little darkroom work. Interestingly, when exhibited this print was preferred in portrait format, especially when viewed in a mirror.

# Light-Painted Flowers

## Creative lighting and lots of patience

by Hisun Wong



The light-painted flower images shown here were created in the mid-1990s. They represent a whole set of images that sold well, and one of which is now exhibited in the Hong Kong Heritage Museum.

I have always been fascinated by the visual impact of painting with light, where light is selectively added to specific portions of the subject and occasionally to the background. In the early 1990s, light-painting was revived by Arron Jones, who designed and marketed a high-end light-painting tool, called HoseMaster.

At first, it was not easy to find unusual and perfectly shaped flower specimens locally, so I ended up buying imported flowers to obtain the perfection I wanted. My regular home studio, set up in the attic and lit by a skylight window, was of little use, since light-painting requires a darkened room.

### The Concept

I use a light-painting technique, which can selectively emphasize the main features of the flower through applied light. The placement of a solitary flower in the photograph emphasizes the flower as a whole. By way of comparison, a traditional approach, using soft lighting from an overhead soft box, produces a textbook reproduction of the flower rather than an artistic interpretation. At first, I used dark backgrounds as they were easier to manage during light-painting, but as I gained more experience, I began using light backgrounds in light-painting photography to produce high-key images, such as the one on this page. The emotional impact of a dark background is very different from the livelier effect of a light background. Not only do the dark tones of a low-key image suggest something mysterious, but more importantly, the viewer's attention is drawn to the powerful highlighted portions of the flower. Conversely, high-key images can be more delicate and ethereal.

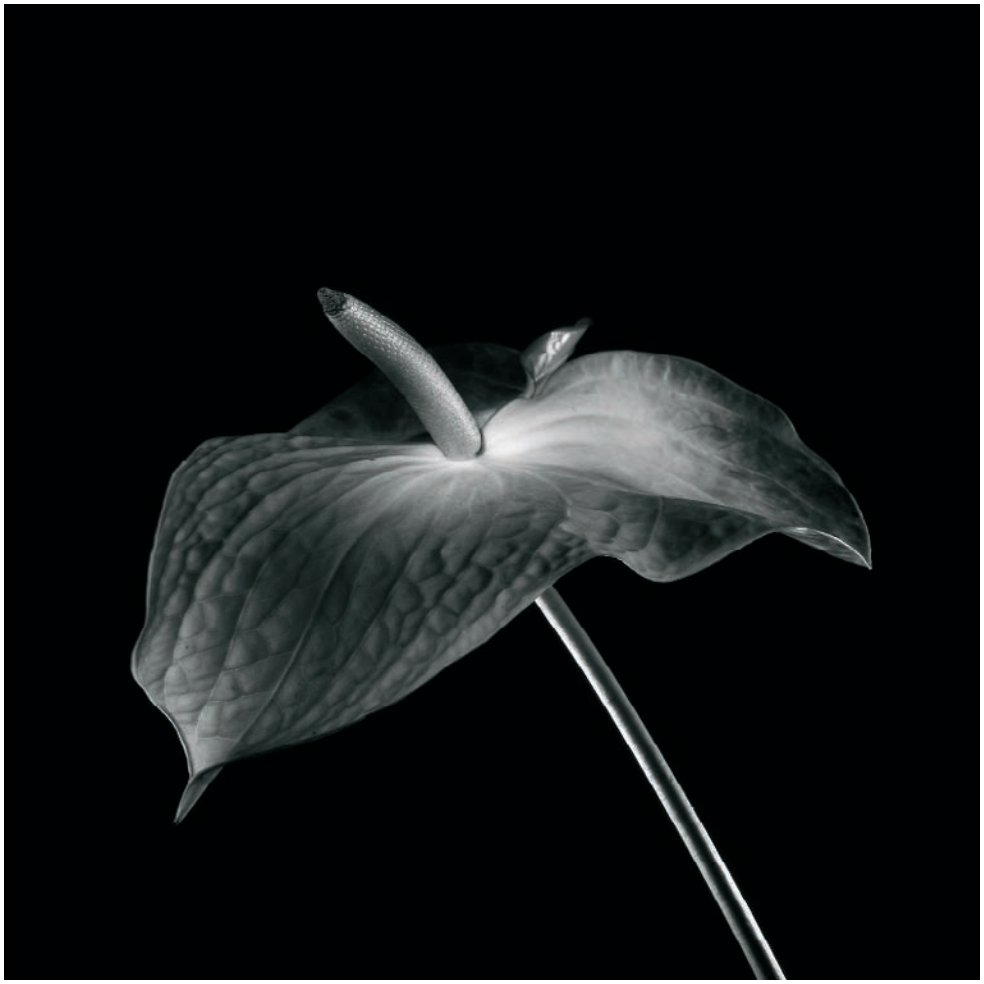
© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50057-0

## The Tools

As I did not own a HoseMaster system at the time, I experimented with a powerful hand torch made by SureFire. Having checked its power was sufficient, I was left with the technical problem of how to measure the exposure. Light-painting uses a continuous but moving light source, and any hesitation creates a hot spot in the photograph. The first step was to measure the torch intensity with my Minolta Flash Meter V. An incident reading of the light beam indicated an exposure of 4 seconds at f/22 at a preset distance. This aperture was chosen to obtain the necessary depth of field and ensure the whole flower appeared sharp in the photograph. Having determined that an exposure time of 4 seconds was required, I adjusted the process with Polaroid film for proofing. Since the time element is critical, the aperture was opened up to accommodate the difference in ISO sensitivities between the emulsions. This clearly affects the depth of field in the test print but keeps the same overall exposure time and light-painting dynamics. Although the exact light path and local exposure duration cannot be precisely repeated when finally using negative film, Polaroid test prints still confirm the broad concept and prepare the mind and hand for the actual photograph.

My shooting table consisted of a simple tabletop covered with black cloth, which was also large enough to serve as the background. A long and narrow vase held the flowers in place. The camera was securely mounted on a tripod to ensure no significant vibration occurred during the long exposure time, required for the light-painting movements.



## Taking the Photographs

At first, the light-painting technique seems disarmingly simple. One opens the shutter, paints the light according to the mental plan and closes the shutter again. However, at the end of my first session, I had exposed several rolls of film, not really knowing if I had succeeded until they were processed.

Even with more practice, it is rather difficult to create a desired effect with confidence, since we can only anticipate the outcome of combined exposures. Some of the guesswork can be eliminated by deploying a digital camera, alongside the film camera, to quickly verify the result of combined exposures. In any event, the torch has to be kept moving to avoid hot-spots, and to create the required exposure, some areas must be ‘painted over’ repeatedly. The flowers also need to be lit sufficiently, so the viewer can easily identify them as flowers, but not too uniformly, otherwise the result is similar to the bland lighting of a soft box. After all, if that is all we want, we do not need to undergo the complex and unpredictable process of painting with light!

To improve my chances of success, I took a few frames of each flower and moved the torch according to my mental plan, knowing full well that I would never be able to repeat the process exactly. In the end, only a few frames had the sought-after combination of light and exposure, while others either were overexposed in certain areas or had the lighting in the wrong place. My aim was to selectively create an attractive balance of light and exposure. As in any type of photography, subtlety requires patience to be achieved.

# Metalica

## Printing from a less than ideal negative

The Zone System is a great way to control exposure and development, but when working in the studio with a live model, it is not a very practical way to operate. The model is often asked to quickly modify a pose and the lighting is constantly changed, trying different effects, making the typical model shoot a rather busy and even hectic event. The photographer should do his or her best to provide an environment as relaxed as possible, but asking the model to hold every pose long enough to take shadow and highlight readings cannot be part of it.

A reasonable compromise between the time it takes to evaluate the light and a proper exposure for the controlled lighting conditions of a studio is brought

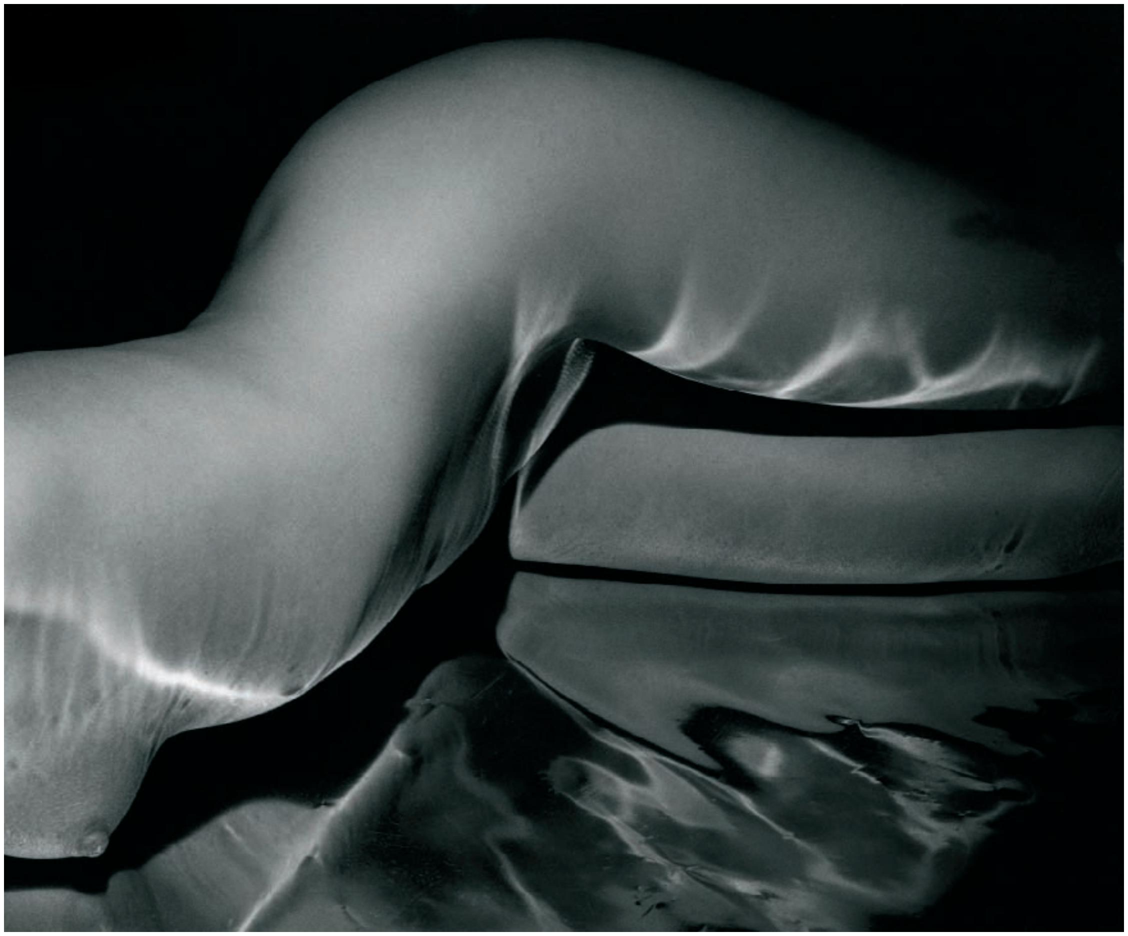


fig.1 final print, with highlight and edge burn-in exposures

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50058-2

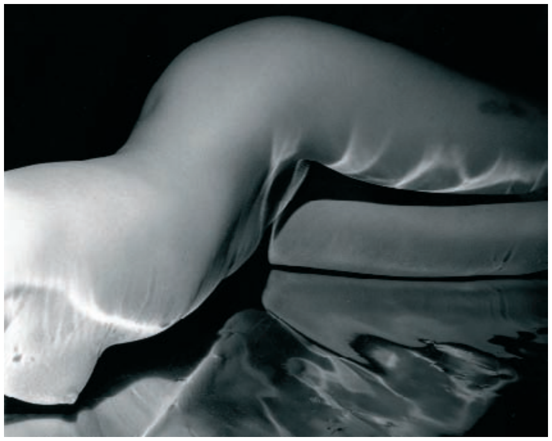


fig.2 (far left) The straight print is optimized for the center of the image, but the highlights of the upper body on the left are completely burned out and the bruise on the leg is very distracting.

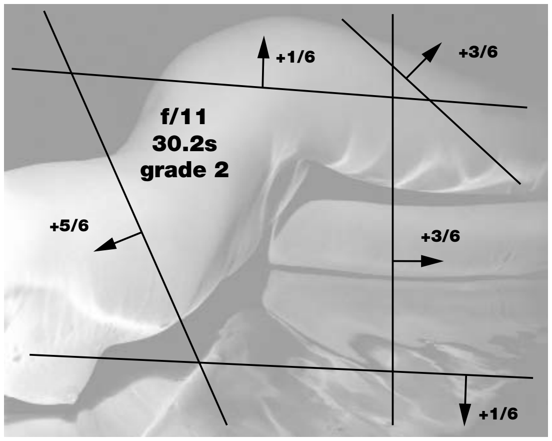


fig.3 (left) A few additional exposures create a balanced print.

by the use of an incident lightmeter. It takes an average light reading with the push of a button, and its typical small white half dome is a familiar sight in many professional studios. The meter is placed into the scene itself, while pointed towards the camera. Consequently, it measures the light falling onto the scene rather than the light reflected from it and the subject tones themselves are not part of the measurement. As a result, the incident reading is equivalent to a reflective lightmeter reading of a gray card.

The drawback is that the subject brightness range cannot be detected with just one measurement. The exposure is centered on Zone V, with shadows and highlights having sufficient detail as long as the lighting ratio is normal. However, this approach can lead to unsatisfactory detail in shadows and highlights whenever the subject brightness range is greater or smaller than 5 stops. This is exactly what happened with the negative for 'Metalica'.

Metalica is a figure study I did in November of 1996. The model was lying sideways on a metal foil, and I was interested in capturing the lines and shapes of the human form, playfully emphasized by multiple light reflections from the foil. The professional lighting system of the studio was turned off and the only light source was one 12-volt halogen light bulb, the kind you see used in shopping window displays. This single, almost point like light source, bounced off the wavy foil in many directions, creating unexpected but interesting light patterns on the body.

The desired affect was achieved, but the final negative revealed that the single bulb had created a very harsh lighting condition. The incident light reading and the correct exposure for the midtones, in conjunction with the normal development of the film, had created a negative density range, which was far beyond normal with very dense highlights in the upper body.

It is my typical recommendation to set the exposure for the highlights and to control the shadows with paper contrast, but this approach required a bit of artistic license and interpretation in order to make this particular print work. Fig.2 shows the straight print, where the exposure is controlled for the flesh tones and the reflection highlights in the center, while ignoring the upper body highlights.

I decided that the flesh tones in the center were about right, and I liked the light reflections in this area as well. To me, this was the most important area of the image and should be left as it was. The print contrast at grade 2 created detailed shadows and rendered the foil as intended, but the bruise on the left leg was very distracting. Fig.3 shows the final printing map and how a few additional exposures balanced the print. The image center was left untouched, the left was burned-in to match the tonal values of the rest of the body, and the bruise was disguised by blending it further into the shadows.

This example shows that printing rules cannot be applied rigidly, but need to be interpreted from case to case. I suggest selecting the print area that is most representative of the desired intent and then to optimize the exposure and contrast to make this area the center of interest. Finally, adjust the rest of the print to support the center of interest, without creating competition and hide any possible distractions.

# Alternative Processes

## Historic photographic processes and digital negatives combined

The invention of photography is based on the fact that silver salts are sensitive to light. However, other metal salts are also light-sensitive and usable for photographic purposes. One of the first to experiment with other metal salts was Sir John Herschel, and in 1842, he published his account on the cyanotype process, which is based on ferric salts.

Herschel was a key figure of early photography, making numerous inventions but also improvements to existing photographic processes. By far his most important contribution, however, was his discovery that sodium thiosulfate is a solvent of silver halides and can be used as a photographic 'fixer'. He is also credited with coining the term 'photography', as well as the terms 'negative' and 'positive'.

Due to the sometimes too aggressive and almost virulent looking prussian-blue color (cyan) of the cyanotype process, it never became really popular for portraiture or other pictorial purposes, in spite of occasional attempts of revival. It did, however, turn out to be a convenient and cost effective way to duplicate text and drawings, and is, therefore, the precursor of the engineering blueprint and photocopying.

In addition to cyanotype, many other historic photographic printing processes are still in use today. They are supported by individuals who love the craft and their distinctive tonal results. Among these processes are albumen, carbon, gum, oil, platinum, palladium, salt and VanDyke or kallitype printing. Compared to modern silver-gelatin, historic process emulsions are relatively slow, because they are predominantly sensitive to UV radiation. Consequently, negative enlargements are impractical and contact printing is the only way to produce a large-size print, which is often a steep hurdle, as it calls for a large, full-size negative.

This creates a unique opportunity for the use of digital negatives, allowing the gap to be bridged between historic photographic processes and modern digital imaging. The image shown here is a 'true' cyanotype made from a digital-camera file. The digital image was processed as described in the chapter 'Digital Negatives for Contact Printing', and a halftone negative was made using the imagesetter of a local service bureau. Then, back in the darkroom, a cyanotype was produced in just the same way as Sir John Herschel did it in 1842!

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50059-4

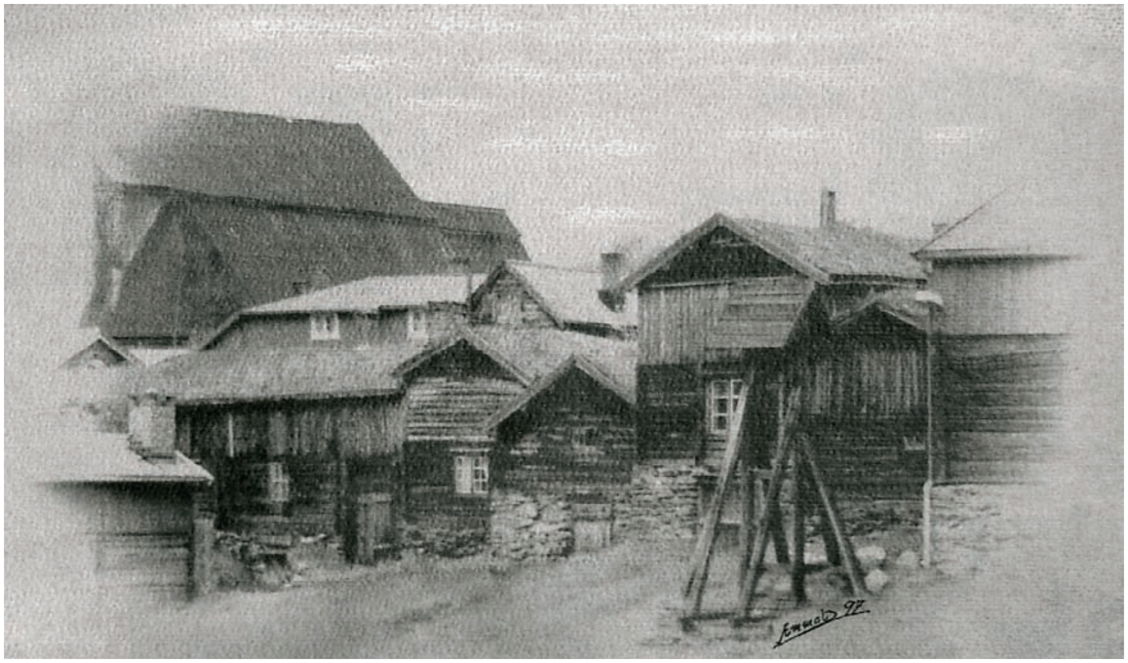


fig.2 This is an example of a gum print made from a digital negative. The scene was originally photographed in Norway in 1991 with a 35-mm film camera on Ilford XP2. Years later, the negative was scanned and an inkjet negative was made, from which this gum print was created in 1997.

(image © 1997 by Andreas Emmel, all rights reserved)

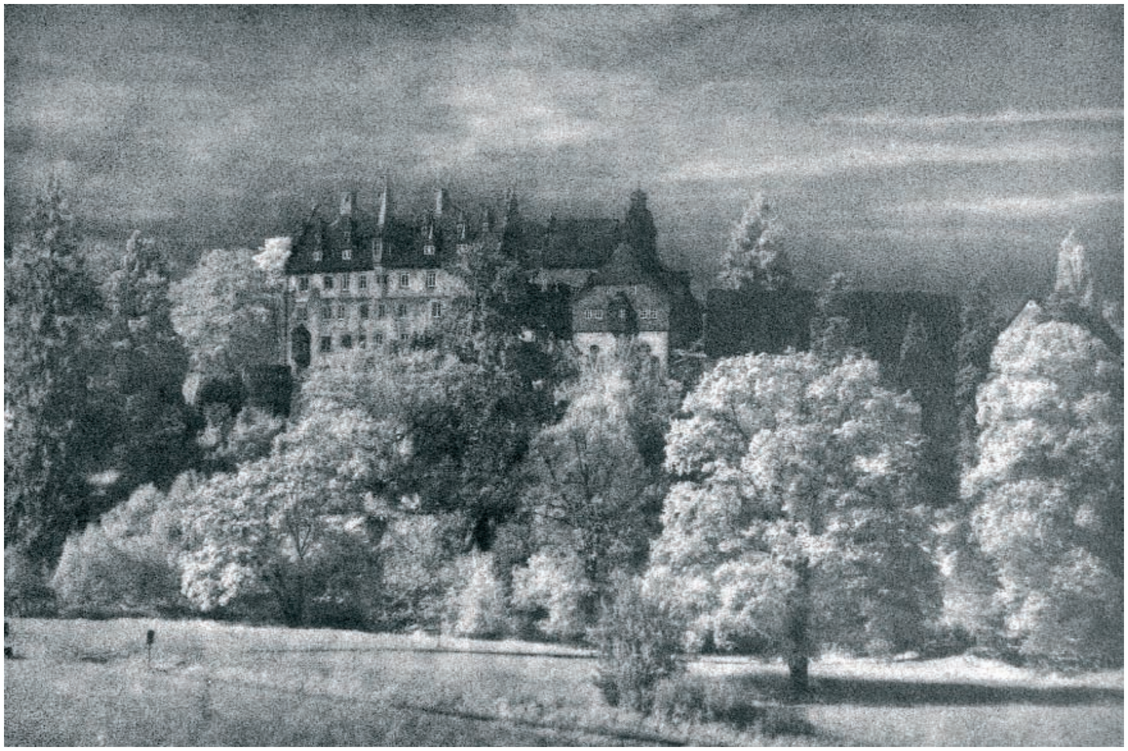


fig.3 This is an example of an oil print made from a digital negative. The scene, Schloss Eisenbach in Germany, was originally photographed in 2005 with a digital camera, using its infrared modus and an infrared filter. A year later, a digital inkjet negative was made, from which this beautiful oil print was created.

(image © 2006 by Andreas Emmel, all rights reserved)

fig.1 (opposite page) This cyanotype print was made in 2004 from a digital-camera file by creating a halftone negative and then contact printing it in just the same way as John Herschel did in 1842!

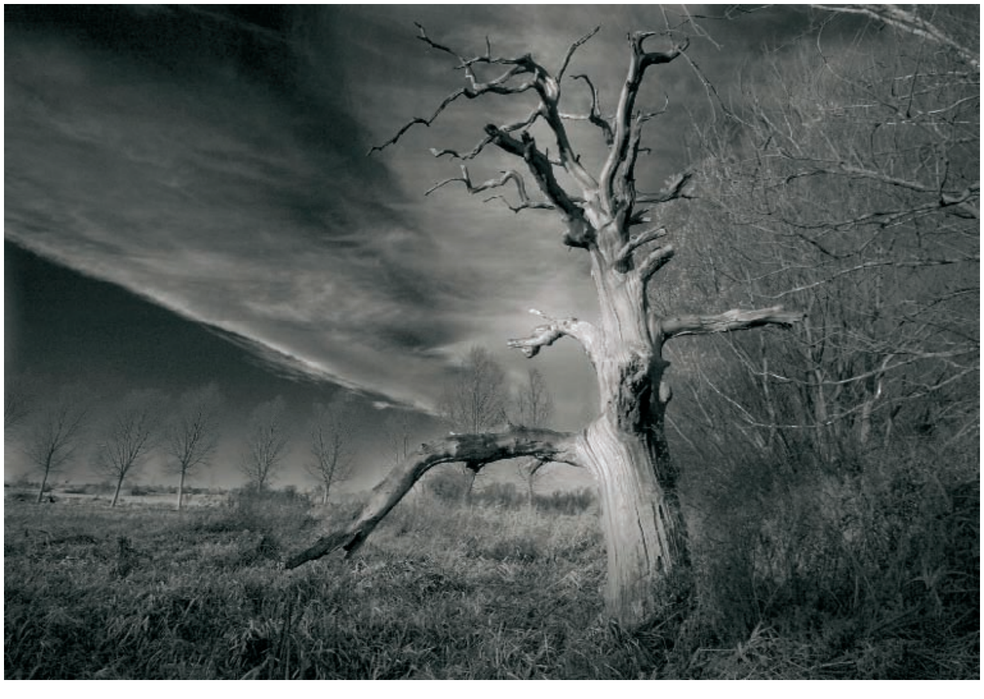
# MonoLog

## Right place, right time, wrong camera

If the ultimate frustration for a photographer is to pass a fantastic scene without a camera, a close second must be to have the wrong film or camera on your person at the time. This is about an image made under such conditions (fig.1). Its bold composition, dramatic lighting and unusual sky shout film camera and orange filter, followed by a toned full-scale fiber print.

A photographer sees an image where others walk by. One November evening in 2006, as he walked along the banks of the Chelmer and Blackwater navigation canal in Essex, England, all that Gerry Sexton had at his disposal was a digital SLR. Later on, at home and after a little experimentation on his computer, it was obvious that dramatic monochrome rendering made the most favorable impression. Unimpressed by the quality of monochrome prints from his inkjet printer, Gerry turned to me for advice. This image, on the wrong medium and in color (see fig.2), is a perfect example of where an alternative method might lead to a better result. I suggested that a practical application of the digital negative process would recover the situation, and reward the photographer for his artist's eye and incredible luck of being in the right place at the right time.

fig.1 The final analog print, using Agfa Multicontrast Classic paper toned in Viradon, has a little judicial burning-in around the edges and at the corners.
(image © 2006 by Gerry Sexton, all rights reserved)



### Image Processing

The original color image was generated from a raw 12-Mpixel digital-camera file. In this case, good technique and optics ensured sufficient image resolution to produce an inkjet print of reasonable quality at 300 dpi and 11x14 inches. Fortunately, the image had not been over-sharpened but the original raw file had been accidentally deleted. (It happens to all of us, but when was the last time you lost a negative?) The color image, enhanced at the time with a polarizing filter, already suggests a monochrome rendering, with cloud streaks emanating from the naked weather-bleached trunk. A straight conversion is obtained with our recommended starting-point channel-mixer settings (see fig.3a) to produce the literal monochrome print in fig.3. Further experimentation with this control resulted in the final mixer settings (see fig.4a), which suppress blue and boost red luminances, to produce the more dramatic monochrome rendering in fig.4. A bonus of this tonal manipulation was the increase in local contrast between the living and dead grass stalks that punctuate an otherwise plain foreground. The on-screen image in fig.4 then appeared as if it had been photographed through a red filter on B&W film. Unfortunately, it also showed the first signs of tonal posterization and some noise in the shadow

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50060-0

areas. Consequently, I decided to delegate any additional dodging and burning manipulations to the less damaging techniques of the darkroom. But first, the on-screen image (fig.4) was printed with an inkjet printer onto glossy paper to later serve as a darkroom reference for the final silver-gelatin print.

Following the proposed digital-to-negative process, outlined in 'The Copy-Print Process', a transfer function was now applied to the on-screen image (fig.4). This transfer function had been previously determined for the combination of film, developer and paper intended for the final print. The resulting flat, odd-looking image was also printed, but this time onto smooth, matt inkjet paper for the sole purpose of copying it onto film.

## Wet Processing

The flat inkjet copy print was attached to a diffusely lit wall in my conservatory, captured onto 4x5 Kodak Tri-X with an Ebony field camera and then processed normally in D-76 (1+1). The resulting large-format copy negative was modestly enlarged to 11x14 inches for display purposes, using my dwindling stock of Agfa Multicontrast Classic. The current equivalent to this paper is Ilford's Multigrade IV, but I prefer the warmer image tones that the Agfa paper produces after selenium and sulfide toning. A split-grade exposure using an Ilford 500 enlarger head and an RH Designs Analyser 500 meter/timer combination was made. The cloud and grass were dodged during the green exposure to lighten their highlights without weakening the dark tones. One last manipulation was to add 1/4 stop extra exposure to each edge of the print, fanning it in with a piece of flexible red card to avoid telltale bands.

Finally, to give a depth and resonance to the image, the fully fixed and washed print was lightly selenium toned and then toned in Agfa Viradon for 2 minutes at its recommended dilution. This brown toner is apt to catch out the unwary. With some papers, the apparent lack of activity in the toning bath is made up for in the wash, where, unless it is monitored and arrested in a wash aid or a toner stop bath, the print will change to a deep chocolate color by the time it is fully washed. Finally, the print was rubbed lightly under water to remove any surface deposits, rinsed in Sistan and hung up to dry. The effort of creating this print was considerable, and it serves as a reminder that the best camera in the world is useless, if it stays at home.

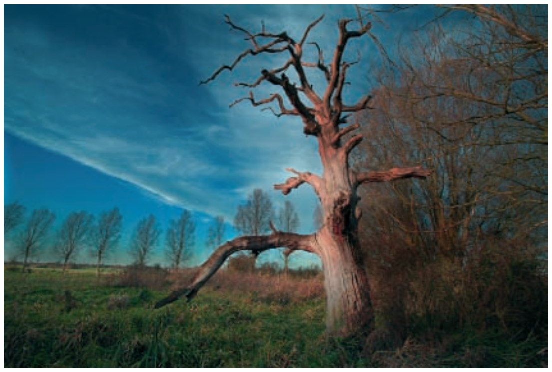


fig.2 The color contrast of this image is the key to making a dynamic monochrome print.

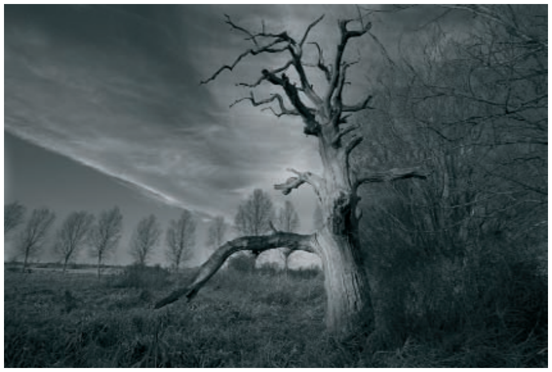
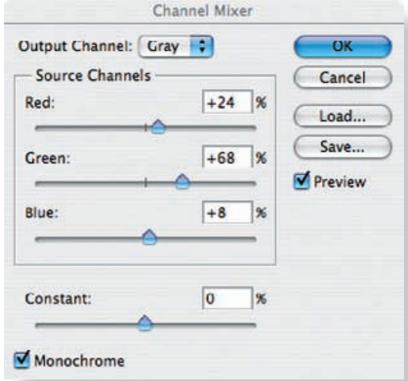


fig.3 Applying the starting-point channel-mixer settings in fig.3a to the color image produces a monochrome image with normal tonal separation.



Channel Mixer

Output Channel: Gray

Source Channels

Red: +24 %

Green: +68 %

Blue: +8 %

Constant: 0 %

☑ Monochrome

☑ Preview

fig.3a These channel-mixer settings are a good starting point for color to monochrome conversions.

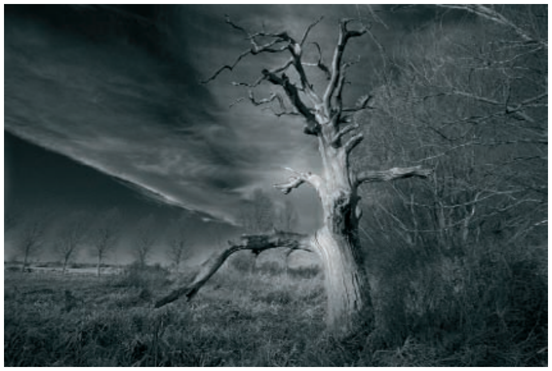
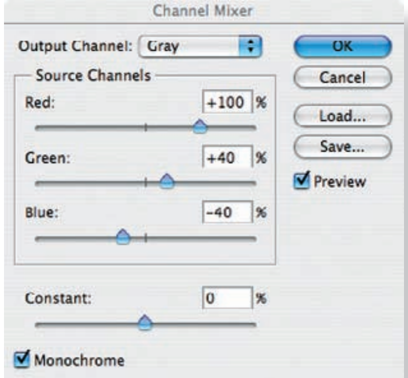


fig.4 Applying the custom channel-mixer settings in fig.4a to the color image translates image colors into a dynamic monochrome representation, while exploiting the primary RGB elements of the color scene.



Channel Mixer

Output Channel: Gray

Source Channels

Red: +100 %

Green: +40 %

Blue: -40 %

Constant: 0 %

☑ Monochrome

☑ Preview

fig.4a These channel-mixer settings lighten warm colors and darken cool colors, similar to red on-camera filtration with B&W film.

# Parnham Doorway

## Toning with mood

During a summer vacation trip to Dorset in England, my family happened upon Parnham House. The building is the creative center of the master cabinetmaker, John Makepeace, with to a splendid display of his and others' contemporary furniture. All the items are fashioned with the utmost attention to design, detail and craftsmanship within the workshops behind the country house. Since it looked like the kind of place that would offer some photographic opportunities, as well as being of interest to the rest of the family, we went to investigate.

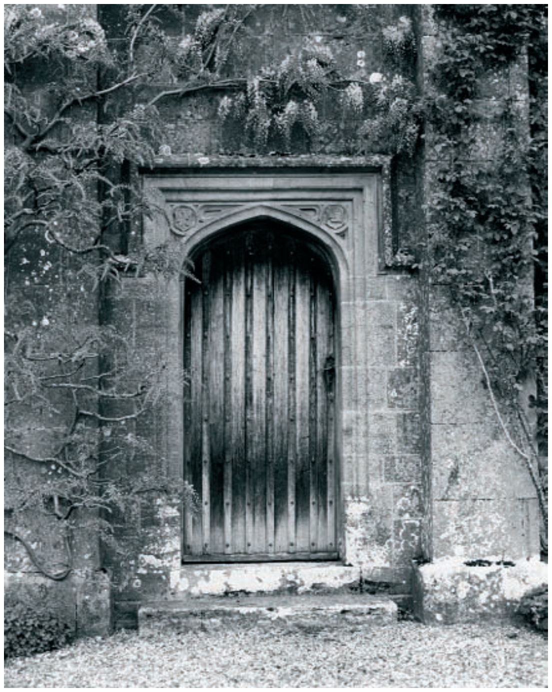


fig.1 This is the work print, exposed for 4.4 seconds with filter 3 on Agfa Multicontrast Premium paper.

Unfortunately, it was only an hour until closing and the light was fading fast due to gathering gray clouds. I immediately set out to work on the wonderfully weathered exterior with warm stonework, withered wisteria and original oak doorways by quickly setting up the Hasselblad 503CX and tripod. The only film I had was the slow, but fine-grained, Agfa APX25, hardly the best choice for low light and the movement of the leaves in the light breeze. Working rapidly, I used my spotmeter to take a reading of the shadow under the arch and adjusted by 3 stops to place it on Zone II. The lighting was flat, so I did not trouble myself with extreme contrast or compensation development. Even so, I had to use a 1 second exposure at f/8 to make the exposure.

After several minutes of waiting for all of the wisteria blooms to be still and metering the falling light level, I decided to get one shot 'in the bag' just in case. It was a good thing too, because the gathering gray clouds began precipitating over my equipment shortly afterwards, further reducing the already dim light.

### Processing

Back in the darkroom, I developed APX25 in its family developer, Rodinal. Throughout my years of using Agfa B&W films, I have always found them to respond best to this ancient developer, which is still considered to be a benchmark for others. In Rodinal, grain is well defined and bitingly sharp. Other developers such as Ilford Ilfotec HC, Tetenal Ultrafin and Ilford Perceptol yield a much reduced film speed, which is critically low anyway in the case of the slow APX25. This remarkable film was, unfortunately, discontinued by Agfa in 2000. It seems that those seeking ultimate quality are moving up format and use the latest emulsions such as Ilford's Delta or Kodak's TMax range of films.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50061-2

The straight print in fig.1 was made on Agfa Multicontrast Premium without the need for a test strip. I used my darkroom 'Analyser' to place the metered door shadow and lichen highlights on the tone scale, using the exposure and contrast buttons. The print was exposed with a contrast filter 3 at 4.4 seconds.

Initial examination of the straight print showed some print imbalance issues and a rather austere neutrality. To keep the emphasis on the doorway, the top and sides were burned-in for 1/2 stop at a low filter setting, and the bottom received 1 stop with the same filtration, toning down the path to something less eye-catching. A quick look around the borders (see fig.1) revealed an annoying highlight at the bottom right, screaming for attention. An additional 1/2 stop local exposure with a low-contrast filter put it in its place.

To add a hint of nostalgia to the image, I used a combination of direct and indirect sepia toning (see 'Sulfide Toning' in 'Archival Print Processing'). After development, stop and two-bath fixing, the print was first washed for 5 minutes to significantly reduce residual fixer. This is important, because left in the print, this fixer in combination with the bleach, used later during indirect toning, will remove faint, delicate highlights. Then, the print was directly toned in sepia, also protecting the dark shadow tones against this bleach, while converting them to neutral-warm tones. Finally, the print was indirectly toned, that is first rinsed and briefly bleached in a strong solution, reducing only the highlights, and then toned in sepia once more to redevelop them to silver sulfide. This gives the stonework its natural appeal, while the protected shadow tones are kept neutral-warm.

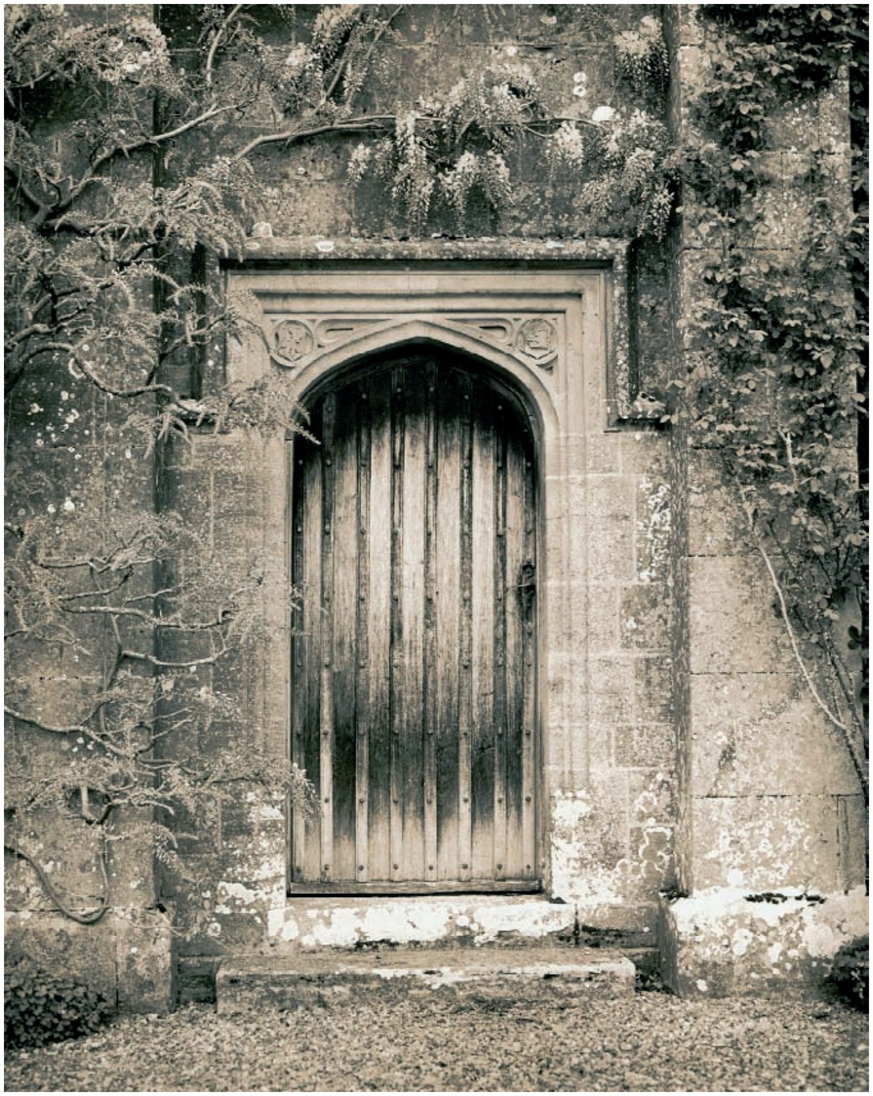


fig.2 This is the final print with 1/2-stop edge-burn at the sides and top, using filter 0. The bottom received 1 stop more exposure with filter 0 to prevent the path from competing with the door. The print was combination toned to add warm highlights, while preserving neutral shadow tones.

# Large-Format Nudes

## Using a view camera in the studio

What is the best camera? Leaving obvious financial restrictions aside, Ansel Adams purportedly answered this question, “The biggest you can carry”. This answer does not come as a surprise from a great landscape photographer, who was well aware of the inherent benefits of a large negative. Alternatively, the optimum camera choice may depend on the photographic subject. Allowing the photographic application itself to be the guide pays tribute to the fact that camera versatility changes with negative size. As the negative format increases, the weight of the equipment typically goes up with it and electronic conveniences diminish. This gives smaller formats the edge, if speed is of the essence, but at the unavoidable expense of image quality. To prepare themselves for all possible photographic challenges, many photographers invest, therefore, in a 35-mm outfit for action photography, a medium-format outfit for studio and portrait photography, and in a large-format (4x5 or larger) outfit for architecture and landscape photography. These task-dependent equipment preferences are commonly accepted to be reasonable compromises between image quality and speed of operation.

So, what is the best equipment for fine-art nude photography? Most of my work in this area is done in a professional studio, and my equipment preference for portrait and nude has always been a medium-format camera with normal to slightly long focal lengths. Nevertheless, I found it intriguing to discover if there is any benefit in using a large-format camera for studio nudes. After all, many well-known fine-art nudes have been made with large-format equipment in the past.

I work mostly with amateur models, but this time, I selected a more experienced professional model. The reason being, I anticipated longer delays between sets and shots, due to the larger camera and my lack of familiarity with it. Therefore, I wanted a patient and

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50062-4

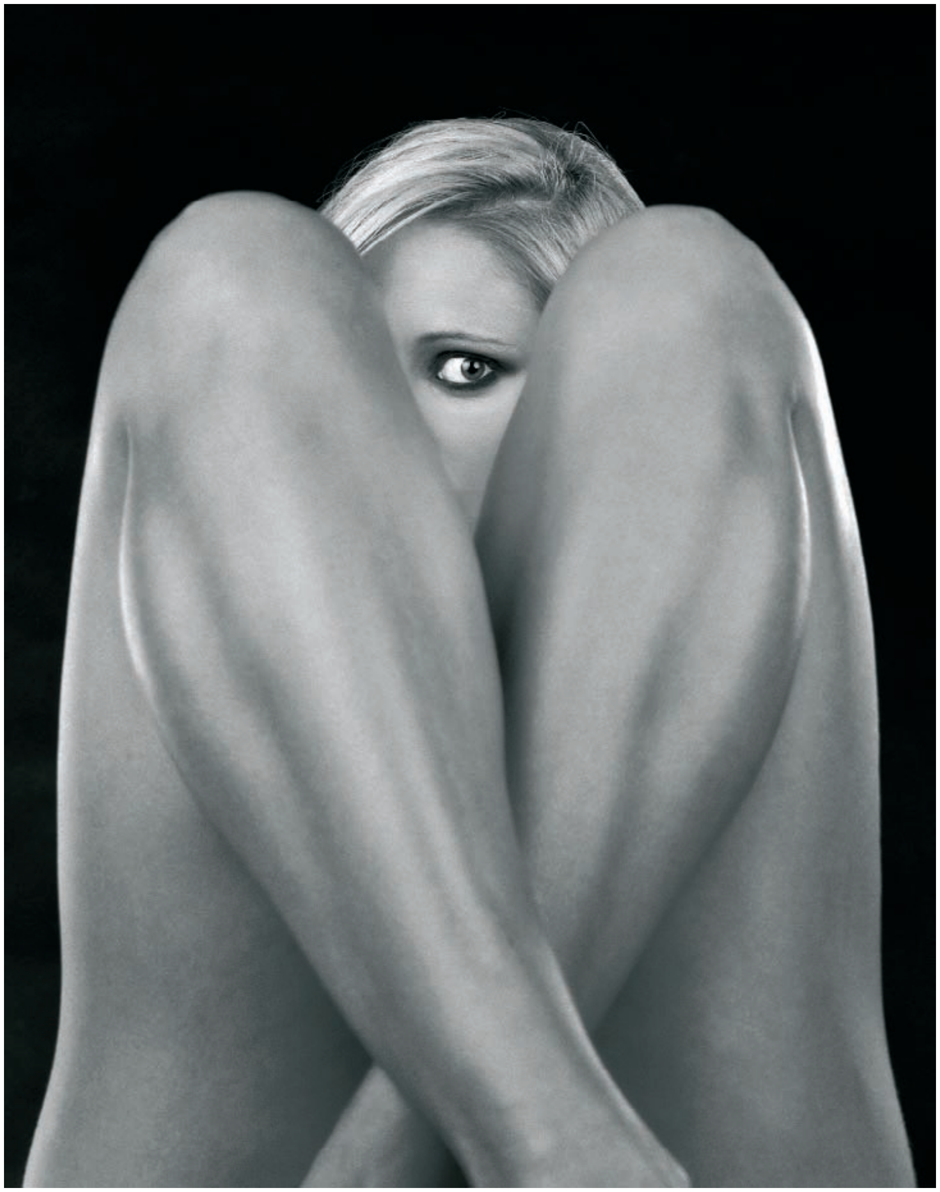
more relaxed model, a character trait not always found with less-experienced amateurs. Other than that, the objective was to concentrate purely on the camera differences alone, and hence, my normal working preparation and operation was not changed, apart from selecting a different camera and type of model. After juggling all involved schedules, model, studio owner, make-up artist, lighting-assistant and my own, we agreed on a day and time. To take no chances, I booked the studio for the whole day.

The decision of which camera to take took me a while. In the end, I selected a 4x5 metal-field camera with a 210 mm lens. This selection comes with a few restrictions, but it represents standard and commonly used large-format equipment, making the test more valuable to others. The camera choice turned out to be no serious handicap, but the focal length was a bit short for this type of work. Next time, I will get an additional lens of at least 300 mm focal length. The film selection was easier. I rarely use anything but TMax-400 and saw no need to change that here. At the end of the day, 24 sheets of film were exposed and all received a normal development in Ilford's ID-11 1+1 for 10 minutes. It is wonderful to have so much control over the light in the studio.

A small selection of these images is shown here. None of these images really show off the flexibility and potential of a view camera — I might leave that for another session — but making them gave me a pretty good idea of what it takes to work with a large-format camera in the studio. Here is a small summary of the experiences made that day.

Setting up the view camera and framing the scene takes me just as long as doing the same with my Hasselblad. The weight difference is minimal, and framing the shot upside-down does not bother me too much. It is something to get used to, though. It does, however, take a bit longer to focus a view camera. Checking the focus on the ground glass just takes more time than doing it in a viewfinder. On the other hand, some time was saved, because there was no need to change film. My film holders were loaded the night before, and 24 frames were enough for the whole day.

Until I actually used the view camera in the studio, it had not occurred to me that I, obviously, would not be able to see the focused image on the ground glass anymore, once the film holder was inserted. Sure, rough posing is done before and while the shot is framed, but a lot of fine-tuning is still done after the image is, and hopefully stays, in focus. Often, the photographer needs to direct or wait for optimum facial and body expression. The make-up artist might have to get into the frame again to correct the hair, or we have to wait for a light to be moved slightly into an optimum position. During all this time, the film holder blocks the view onto the ground glass, and we



are working 'blind'. Sounds like a big handicap and a potential risk for poorly framed or focused images. Well, none of this happened during our shoot. Of course, if the shot needs more than a minor modification in composition, we need to pull the film holder, frame and focus again, but that does not happen very often while creating portraits or nudes. Nevertheless, it is best to plan the shot carefully up-front and leave as little as possible to chance. Several dry runs are better than one out-of-focus image.

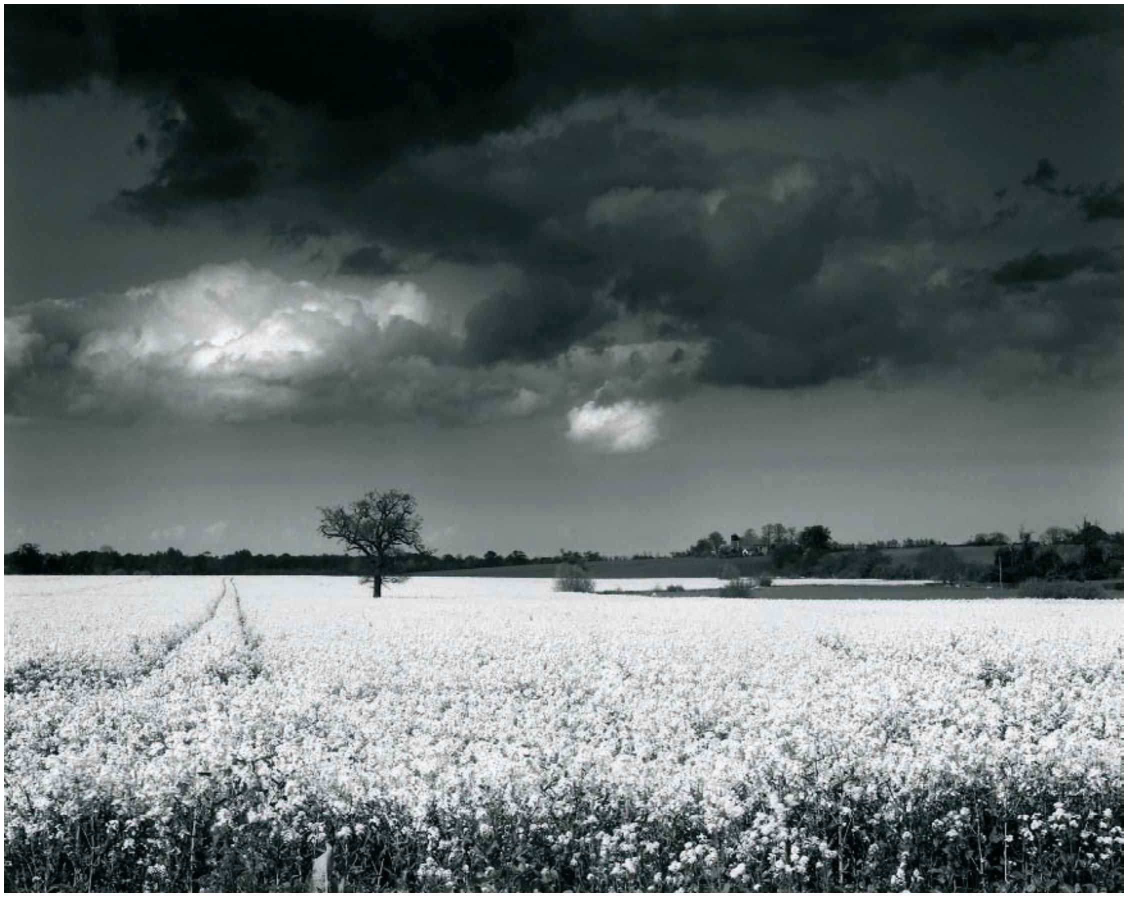
One benefit of using a view camera comes, of course, with the larger negative format itself. Assuming one has the darkroom equipment to support the larger negative, it is just easier to handle, leaves more opportunity for modifications such as retouching and unsharp masking, is far less prone to dust-related issues, and has unbeatable clarity, tonality and resolution with little or no grain. Overall, I agree that the large-format camera, compared to the medium-format camera, did slow me down on the shoot itself somewhat. But this was by no means a bad thing. The large-format camera inherently forces the photographer to compose, frame and focus more carefully. In my opinion, this often replaces potential serendipity with strategy, and that usually makes for the better picture.

All images shown here were taken with a Toyo 45AX metal-field camera and a Nikkor-W 210mm f/5.6 lens at f/16 on Kodak TMax-400 sheet film. The film was rated at EI-250 and developed in Ilford's ID-11 1+1 for 10 minutes. The prints were made on Ilford Multigrade IV with a Durst L-1200, using an EL-Nikkor 150mm f/5.6 enlarging lens, and then developed in Agfa Neutol WA 1+7.

# Rape Field

## A little 'liquid light' can go a long way

In Southeast England, rape fields are in full bloom throughout the month of May. The appearance of the entire countryside benefits from the fresh look of these bright yellow fields, announcing summer to be just around the corner. Few can escape the view's demand for attention, simply ignoring it seems impossible, and no photographer can resist the temptation to capture an image of this magnificent exhibition. Color film seems the obvious choice for a scene so full of intense and vibrant color, but I wanted to try something different. It took some confidence knowing the behavior of my favorite materials, some experience in visualization and a never-ending interest in experimentation to load the camera with B&W film.



© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50063-6

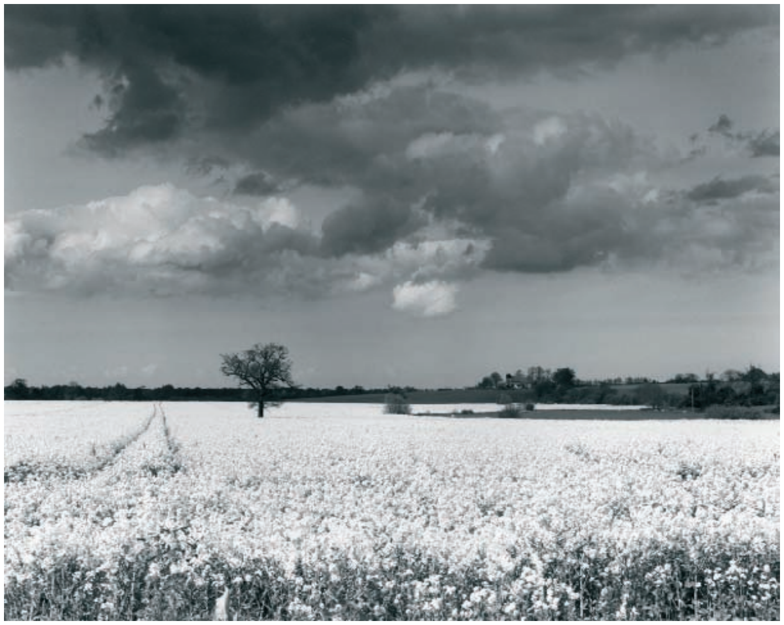
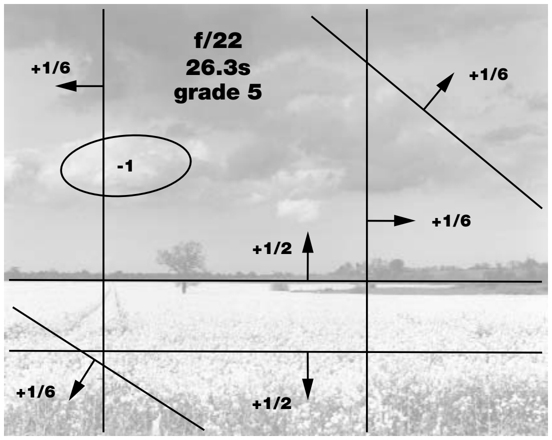


fig.1 (above) The first straight print on grade 5 has the right exposure for the background field but is too light in the foreground and the sky. The foreground requires additional exposure, but the sky would also benefit from a local contrast increase to emphasize the white clouds and make them an additional center of interest.

fig.2 (right) The intermediate printing map shows a sequence of dodging and burning steps to alter the appearance of the print and increase impact. Sky and foreground field are darkened, but the large white cloud is held back during the main exposure to increase the contrast to its surroundings and provide the additional center of interest.



The image shown here was taken in May 2000 between the villages of Billericay and Ingatestone. I drove by this field every day on my way home from work, observing nature's progress all the time, before I decided to take the picture. My mental image of the scene was strong and left little room for compromises. I wanted bright direct sunlight to make the rape glow, dark sky to provide a contrast and stormy clouds to give some extra interest. One Sunday, the conditions seemed really promising, and the unexpected tractor tracks offered an additional benefit, enhancing the perspective and leading the viewer into the picture.

Patience was required to get bright sunlight and stormy clouds captured in the same image. The cloud cover was not very dense, but the occasional patches were rarely big enough for the sun to illuminate the entire field at one time, and they didn't seem to come my way. It took 1 1/2 hours until the conditions were right. By then I had many opportunities to set up the Toyo 4x5 field camera, focus the 210 mm lens, take light readings, place tonal values and decide on supporting filtration.

The darkest part of the background was placed on Zone III, and the rape field just in front of the lonely tree fell on Zone VII·5. That was not bright enough for what I had in mind. An orange (15) filter was added, and I expected it to lighten the yellow field by about half a zone. The film was marked for N+1/2 development to elevate the field to Zone VIII·5 and, therefore, borderline white. The orange filter would also help to darken the sky, but the clouds did not measure darker than Zone VI. An additional graduated neutral density (ND0.6) filter reduced the highest clouds by 2 stops to Zone IV. The exposure was made on Kodak TMax-400 at an aperture of f/32 to maximize the depth of field. I rate this film at EI 250 and exposed for 1/8 second, taking into consideration the orange filter.

The film was developed in Kodak's Xtol 1+1 for 8 minutes and the resulting negative turned out to be rather thin. I have never gotten along with Xtol and have since switched to using either D-76 or ID-11. Xtol has a rather limited quantity of active ingredients and when used with a Jobo processor, where the amount of liquid is efficiently minimized, chemical starvation of the highlights may occur. Simply using more developer can cure the problem, a fact I didn't know at the time. To print on grade-2 paper, I typically aim for a negative density range of 1.20, but this negative measured a mere 0.62, which made grade-5 paper a starting point for printing. It is my experience that this type of rescue attempt changes the tonal distribution of the image somewhat and increases visible grain, but the overall print quality does not necessarily suffer. Fig.1 shows the first straight print on grade 5

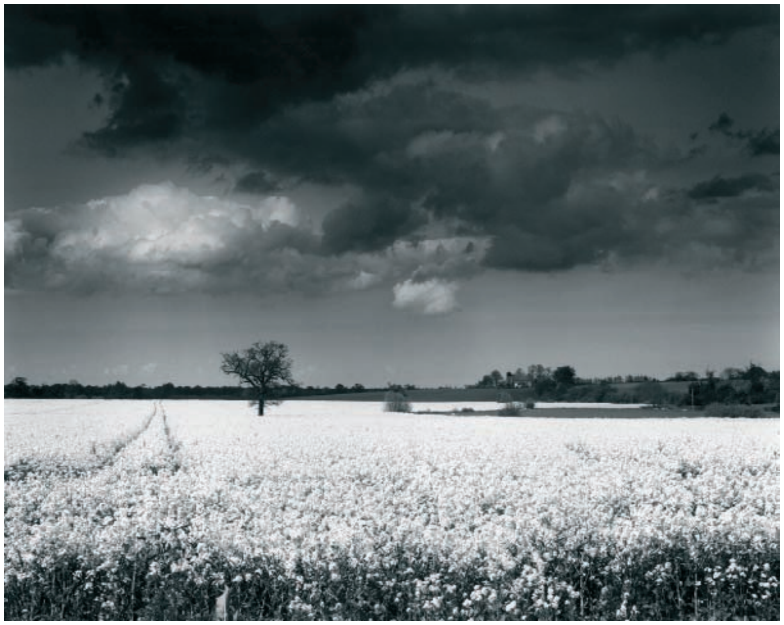


fig.3 (above) The intermediate work print shows the improvement to the foreground and the sky. The dodging efforts for the cloud improved the mood in the sky, and the print has more impact now, but the additional sky exposure also brought much of the cloud density back, leaving it dirty and failing to create much impact.

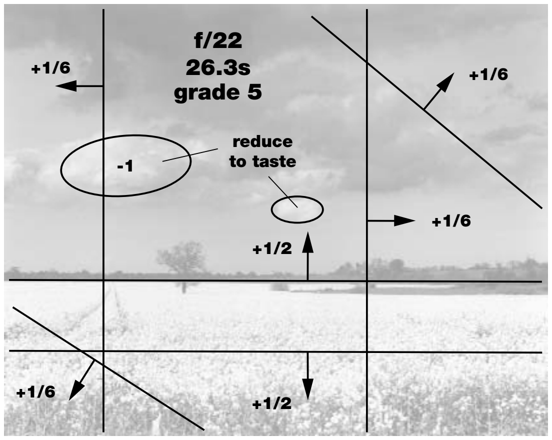


fig.4 (left) The final printing map suggests additional bleaching of the two white clouds. Mix the bleach as described in the text, or purchase Farmer's Reducer, which is a mixture of potassium ferricyanide and fixer. The bleach will reduce print density from shadows and highlights in equal amounts, consequently having proportionally more effect on the highlights, affecting midtones and shadows to a lesser degree. The result is an increase in local contrast.

with correct exposure for the field. It almost has the look of snow as was intended, but several other areas needed improvement. The closest part of the field is too light, but the sky is still dark enough and lacks impact. A mixture of white and dark clouds could add some visual interest to an otherwise peaceful but boring print. The combination of a few burn-ins and the dodging of the cloud are recorded in the printing map in fig.2, which resulted in the work print shown in fig.3. The dodging efforts for the cloud improved the mood of the sky and the print has more impact now, but the additional sky exposure also brought much of the cloud density back, leaving it dirty and failing to create much impact.

In these situations, a little bit of darkroom bleach can be a creative tool, and I recommend to use potassium ferricyanide, 'ferri' or 'liquid light' as I like to refer to it. For this application, you can buy it together with the fixer as Farmer's Reducer or follow the formula in the appendix. I mix 10 g of the powder with 1 liter of water to make a 1% stock solution. This stock solution is then mixed 1+1 with fixer to make a working solution and applied with a brush to the area to be bleached. The working solution is not very stable due to a chemical reaction between the ferri and the fixer, and within 10-15 minutes, it has lost its entire strength. Consequently, I prepare only a small quantity of working solution and make more as I need it.

Alternatively, you can use the ferri alone and finish up with a final fixing bath. However, the full effect of print bleaching is visible only after fixation, and unintended over-bleaching is not uncommon when ferri and fixer are used in sequence. On the other hand, the entire bleaching effect is immediately visible when the above mixture is used, which makes over-bleaching a less-likely occurrence.

To get started, mix 15 ml of ferri stock solution with 15 ml of fixer in a small beaker to a working solution. Place the print onto a horizontal surface and wet it thoroughly. Wipe excess water from the area to be treated, and brush on the working solution. Leave it to work for no more than a few seconds, and then, rinse it off with a water hose. The bleach will reduce print density from shadows and highlights in equal amounts, consequently having proportionally more effect on the highlights, affecting midtones and shadows to a lesser degree. The result is an increase in local contrast. Keep a close eye on the highlights and repeat the process until the desired effect is achieved. If at all possible, keep a wet duplicate print nearby for comparison. Fig.5 shows the sequence of steps as they were used for this image.

During the process, I prefer to keep the print on a horizontal glass surface, because any runoffs will leave unrecoverable telltale marks. Keep in mind that

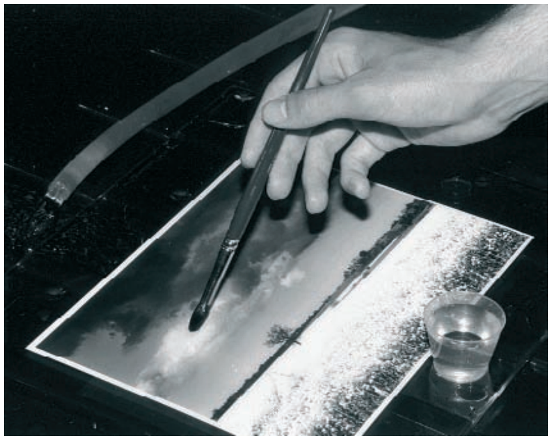


fig.5a The potassium ferricyanide is applied with a brush.

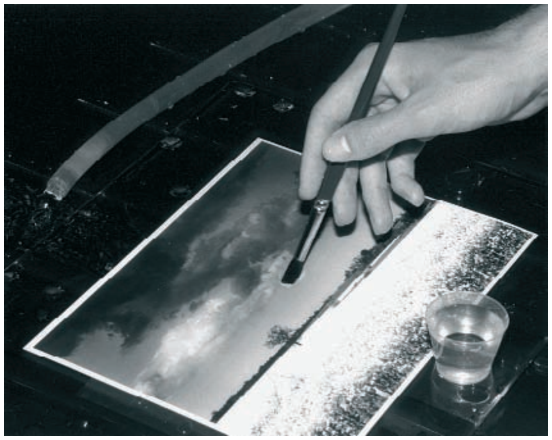


fig.5b Be careful of spills, and leave it to soak only for seconds.

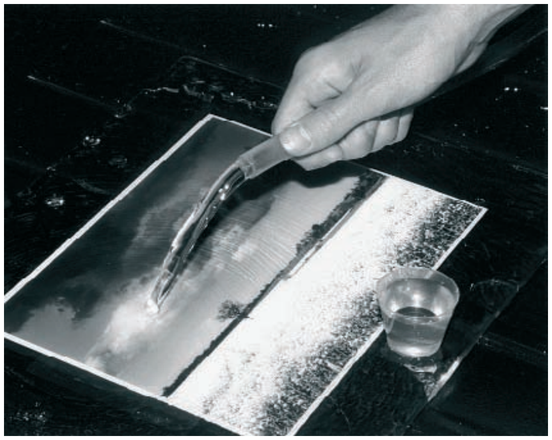


fig.5c Rinse immediately and thoroughly to hide telltale marks.

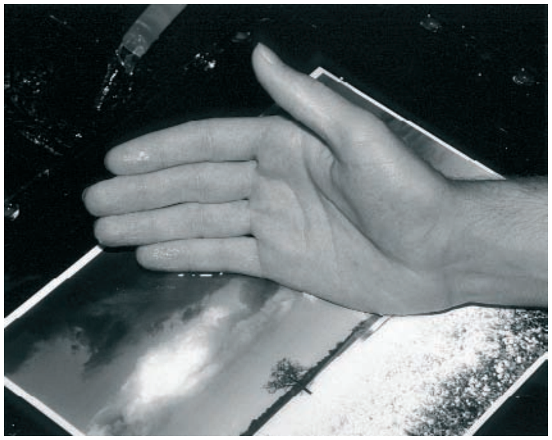


fig.5d Wipe the wet print and repeat the process until done.

any accidental spills will have a similar effect. Up to a point, midtones and shadows can be protected from accidental bleaching through prior selenium or sulfide toning. However, bleaching after toning creates a different shift in print colors than toning after bleaching. Nevertheless, it also creates a unique lith-like color shift of the midtones with selenium-toned prints, which could be used as a creative visual effect. After bleaching, fix the print in fresh fixer and continue with your normal print processing procedure.

The lead image shows the result from bleaching two clouds. Bleaching can make a significant difference to the overall impact of an image. Use it to draw attention to key areas, provide sparkle to highlights, open up otherwise dull shadows, and improve local contrast in general. Bleaching is a valuable technique where other contrast-increasing methods are either too limited, difficult or impractical to apply, as in this case, where the maximum paper grade was already needed for the base print.

# St. Mary's of Buttsbury

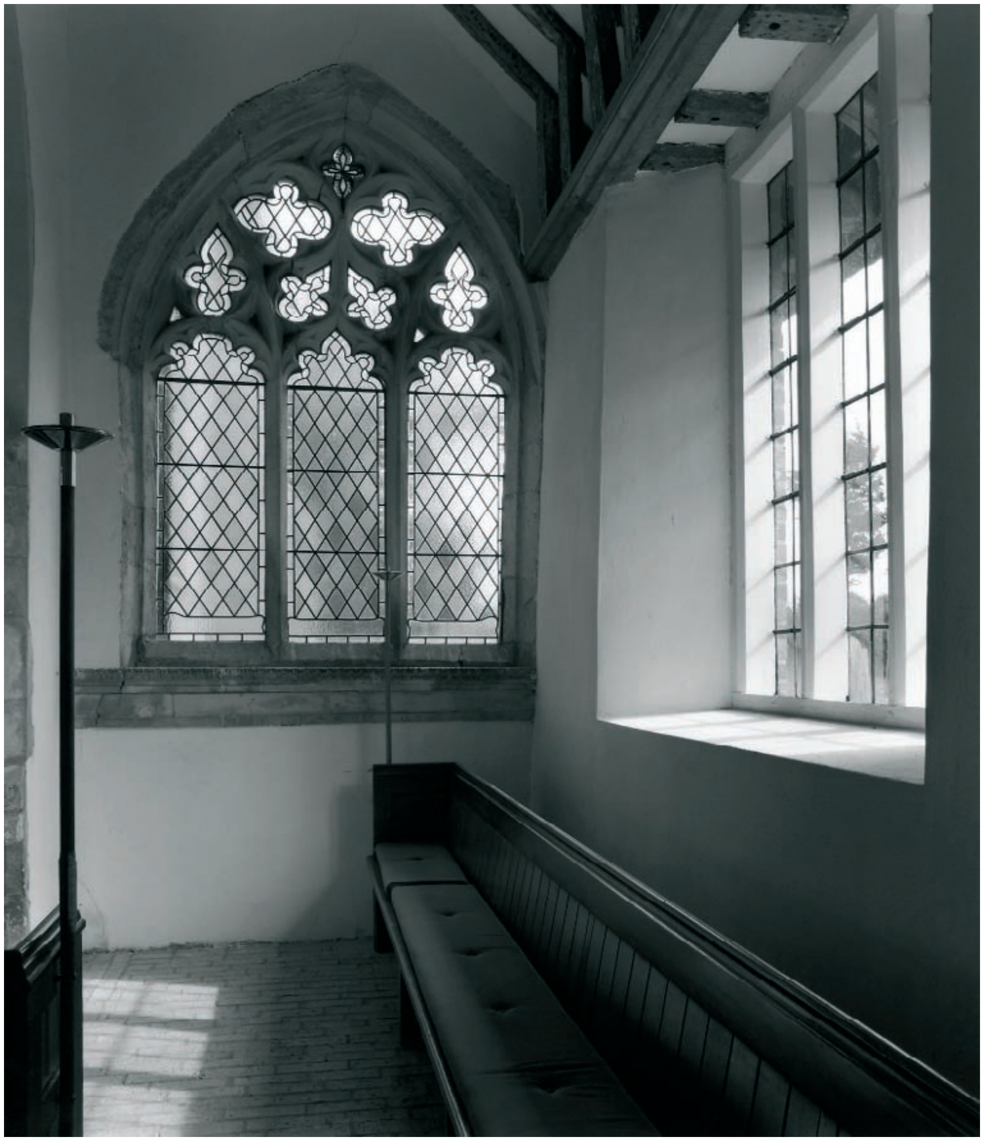
## An English mystery church in Essex

On my way to and from work, I drive right by St. Mary's of Buttsbury. This beautiful English church is located in Essex midway between Stock and Ingatestone, southwest of Chelmsford. It can be found on Ingatestone Road between Elmbrook Farm and Buttsbury Hall Farm.

The church is dedicated to St. Mary and was built in the early 14th century. Throughout the centuries, many people have worshipped at this church, and some have found their final resting place in the shaded churchyard. Unfortunately, nothing is known of the actual village of Buttsbury, which some people think may have been situated around or near the church. Indeed, its position on high ground indicates the probable existence of a village. From the tower, seven church spires can be seen. In medieval times, the nuns from St. Leonard at Stratford came to stay and worship at Buttsbury. One assumption is that the village disappeared with the 'Black Death' in the 14th century. Even so, the church has continued over the years, thanks to the loving care of successive generations.

Today, the small church stands alone surrounded by farmland above a wide grass valley. Once inside, you will find modestly decorated white walls and a ceiling, which had the plaster removed to reveal the oak beams. The two wooden doors have been weathered by the centuries. The square tower is built of flint and stone and has one bell, cast in the 15th century. Parts of the floors are brick from the potteries of Stock and include two tombstones dating 1680 and 1688. Large stained glass windows are a generous and attractive light source during the day.

The church is still used for services and it is open for private prayer during the day when visitors are most welcome. With the ever increasing need for housing in this part of Essex, and the continuing expansion of Ingatestone and Billericay, houses may



© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50064-8

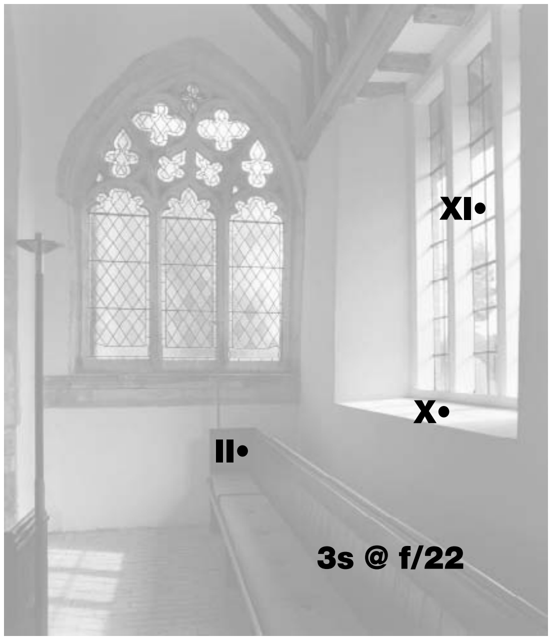


fig.1 The exposure record shows how the zones were placed on the shadows and how they fell on the highlights.

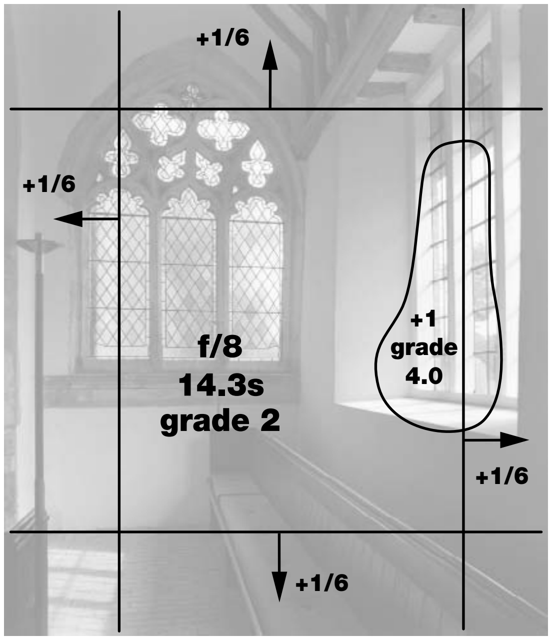


fig.2 The printing map records how the edges and the lower window area of the image were burned down.

again appear in the proximity of the church. Apart from the present farms, Buttsbury may indeed have a full population of its own again. A fitting reward for the loving care that has preserved this beautiful old church over the centuries.

I have stopped often at Buttsbury church and I have taken many images there within the last years. The one shown here was taken on a sunny Saturday afternoon during one of my Zone System classes. It shows one of the stained glass windows and the southeast window to the right. With the Pentax Digital Spotmeter, I placed Zone II·1/3 at the end of the bench, not needing anything but some texture in this area. The rest of the shadows on the bench fell mostly on Zone III. The windowsill fell on Zone X·1/3 and demanded, therefore, N-2 to N-3 development. The glaring center of the window fell on Zone XI·1/3. N-3 development is required to compensate for this large range of luminance, and I have successfully developed TMax-100 in ID-11 for N-3 in the past, but I was worried about losing much of the local contrast if I were to develop the negative that soft. Therefore, I decided to leave the development at N-2 to maintain local contrast. The highlights would need some special attention in the darkroom. I noted the negative for N-2 development in my exposure records. At this point, it was clear that the windowsill would be just above the threshold of the paper, but would have a hint of detail. The rest of the window would need some burning to reveal detail.

My typical film speed for TMax-100 medium-format roll film is EI 64 for normal development, but for N-2 development, I reduce it to EI 40. The reduced development time will 'starve' the shadows, and the extra exposure will help to retain shadow detail. I had the Carl Zeiss Distagon 4/50 mounted to my Hasselblad 501C and stopped it down to f/22 to get the depth of field this image required. This Hasselblad has no front lens tilt, but a subject like this would not have benefited from it anyway. So, the 4x5 stayed in the camera bag. I was left with a measured exposure time of 2 seconds and I extended that time to 3 seconds to compensate for the reciprocity failure. I carry a manual stopwatch with me to time exposure times above 1 second, which is the maximum limit of the Hasselblad lenses.

I normally carry three film backs for the Hasselblad. One is marked 'N' for normal and the two others are marked with 'N-' and 'N+' development, respectively. Often, the '+' and '-' developments are averaged in the darkroom for development, but on this day, all '-' developments ended up at N-2. The negative was developed for 6 minutes in ID-11 diluted 1+1 at 20°C (68°F). The shadows had a transmission density of 0.25 and the windowsill was at 1.3, which is a difference of 1.05, and therefore, a grade-2 paper was needed.

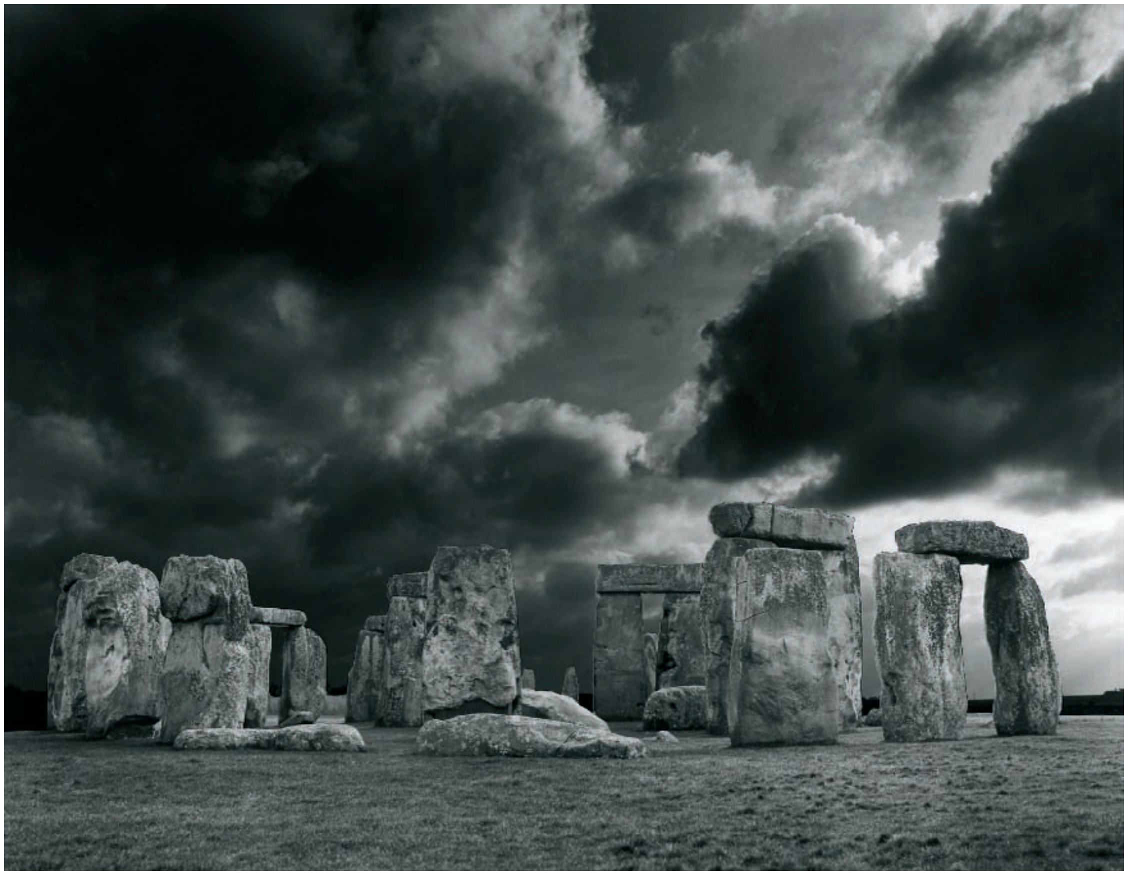
The filters on the color head for my Durst enlarger were set to simulate an ISO grade 2 and the test strip revealed a base exposure of f/8 at 14.3 seconds. I was using 11x14-inch Ilford Multigrade IV fiber base paper. I ended up tilting the head slightly to compensate for some converging lines, which are unavoidable when you point the camera up, unless you use a view camera. The window frames and the candlestick are now parallel to each other. A 1/6-stop edge-burn was applied to 'pull' the viewer into the print. As predicted, the window needed some additional burning down. Another test strip gave a satisfying result with one additional stop of exposure at grade 4 through a hole in my self-made burning card. I often choose a hard burn-in to get some extra local contrast. Here, the leaded frames in the windows needed such a treatment to get the required density into the print. This image represents some of the peace and quiet I always feel when I visit St. Mary's of Buttsbury.

# Stonehenge

## Accepting a printing challenge

The ancient and mysterious stone circle of Stonehenge is located in England, about 10 km north of Salisbury, just off the A303 main road. What visitors see today are the remains of a monument erected between 3000 and 1600 BC. The structure is comprised of an outer circle of large upright standing stones, topped by lintels. Inside the circle, five stone pairs, with a lintel across each pair, once formed a horseshoe. The structure is aligned so that the horseshoe opens to the rising sun at the midsummer solstice.

The original purpose for which Stonehenge was built has been debated for many years. Many scholars believe it was a sacred place of religious worship, while others maintain it was simply a huge astronomical calendar. The mystery may never be solved, but it is clear that only an organized and sophisticated



The final image of Stonehenge was made from a hopeless looking negative. Nevertheless, heavy print manipulation restored the feeling of mystery that surrounds this ancient site.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50065-X

society would have been able to plan and erect such a structure. Ingenuity and an enormous investment of time and labor were needed to transport the stones for many miles, and then shape and raise them.

## Film Exposure and Development

This wasn't my first visit to Stonehenge, but I had never returned with an image capable of representing the mystery of this ancient site. A longer business trip from the US to London provided a free weekend in February of 1997, and with it came a chance to give it another try.

The Hasselblad 501C and Planar 2.8/80 were supported by my traveling tripod, and I was ready to meter the cloudy scene. The darkest area of the stones was placed on Zone III and the brightest clouds fell on Zone IX. Kodak TMax-100 demanded 1/2 s at f/16, and I settled for 'N' development.

## Printing Challenge

After reviewing the contact sheet, I had little hope of a good picture. The small image had no sparkle, and it didn't appear to have a full range of tones, despite the fact that all detail seemed to be there. However, something about this image kept me interested, and I wasn't about to give up easily. Under normal circumstances, I would probably have gone back to shoot the scene again, but unfortunately, by now I was back in the US and flying back to England was not a real option. Moreover, if I were honest with myself, I wouldn't know what to do different the next time anyway. After all, I had used the Zone System to get the whole subject brightness range into the pictorial negative density range.

The first full size straight print, fig.1, verified the information from the contact sheet. The print exposure was optimized for the highlights in the sky, and the contrast was chosen for the bottom of the center right stone to be on a print Zone III. The exposure time used was 12.7 seconds on grade-2 paper. Technically, the print was fine. Everything was there, the sky had plenty of detail and so did the stones, but what a horrid photograph. It had no mood, was not representative of Stonehenge's mystery and communicated none of the feeling I had when I was actually there. Is this a totally hopeless case? Should I give up and cut my losses? Not yet, let's accept the challenge.

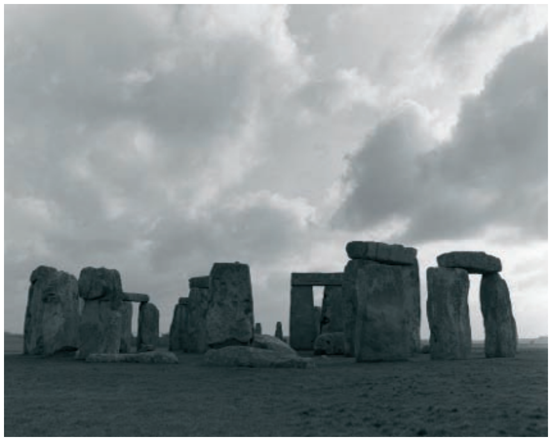


fig.1 The straight print shows that all shadow and highlight detail was captured in the negative. Therefore, film exposure and development were correct, but still, the resulting print on grade 2 has little appeal. The overall contrast is normal, but there are no midtones to speak of, and the image seems to be separated into low-contrast highlights and shadows, which makes for a dull and muddy print.

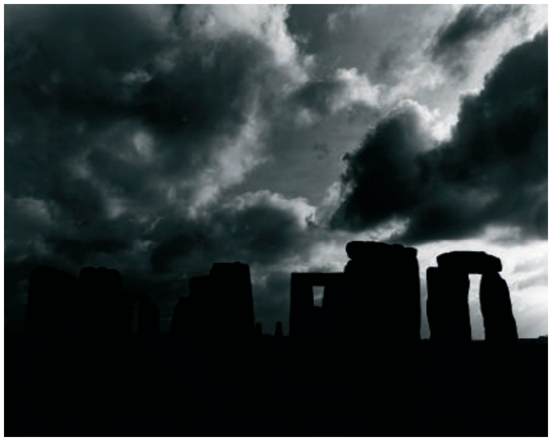


fig.2 A work print optimized for the sky, grade 4.5 at 30.2 seconds, renders the sky at intended but leaves the stones completely black.

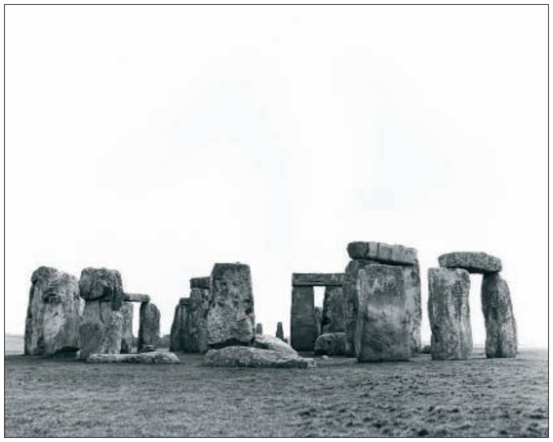


fig.3 A work print optimized for the stones, grade 4.5 at 17.0 seconds, renders the stones at intended but leaves the sky completely white.

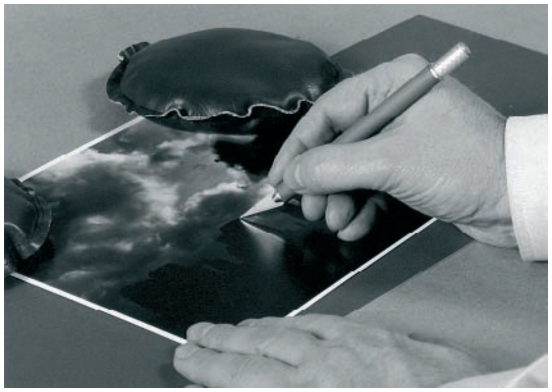


fig.4 A work print can be turned into a customized exposure mask with the help of a sharp utility knife.

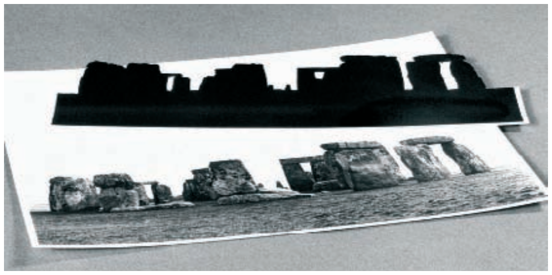


fig.5 Another work print can be used to check the accuracy of the mask. The fine-tuned mask will be carefully aligned with the print to cover the stones during the second exposure.

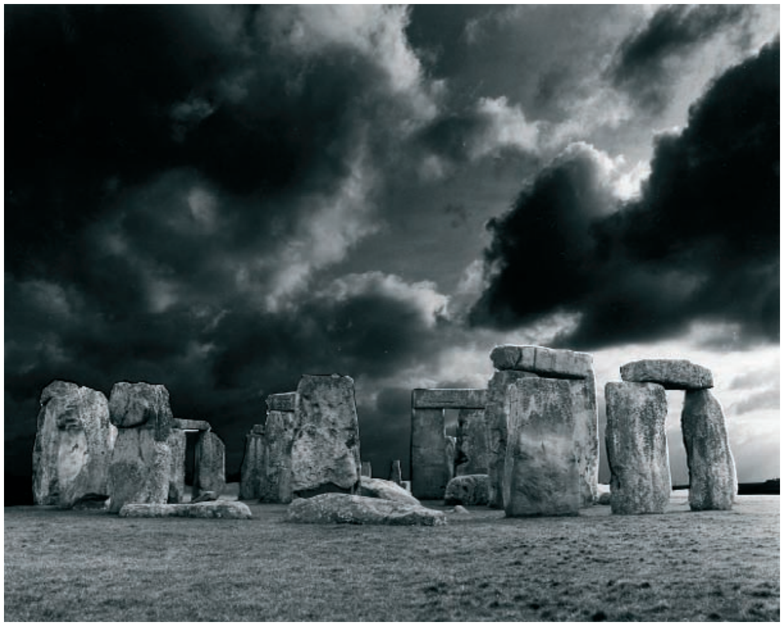


fig.6 A bit of darkroom 'magic' has allowed us to combine the optimized sky and stones into one print. A few attempts may be required to find the best mask position, and a few white marks can be easily spotted away after the print has dried. Additional burning down of the sky was added to the sky to create the final image.

A close inspection revealed the overall contrast between the highlights in the sky and the shadows in the stones was normal and, therefore, printed well on grade-2 paper. However, the image consists mainly of very light tones in the sky and fairly dark tones in the stones. There are no midtones to speak of, and this separates the picture into two areas, each having a very low local contrast.

The solution is to concentrate on each area separately. Fig.2 shows a print optimized for the sky. The highlights in the right half of the sky have the same density as in the straight print, but the paper contrast was increased to grade 4.5, requiring an exposure increase to 30.2 seconds. Now, this is more like it! This is the type of sky I had in mind, and it will definitely help to create and support the right mood for a representative Stonehenge image. However, there was a price to pay for the fact that the stones were ignored in this attempt to create the perfect sky. The foreground went completely black and shows no detail at all. That may have a unique appeal, and some viewers may even prefer it, but it was not my intended outcome for this image.

The next step was to optimize for the stones and in turn ignore the sky, as shown in fig.3. The local contrast was very low again, but printing with grade 4.5 and reducing exposure time to 17.0 seconds allowed me to keep the shadow on the lower stone on Zone III, while raising some of the highlights in the stone to Zone VI and VII. What an improvement. The muddy look is gone and detail in the stone is revealed.

## Putting It All Together

In principle, it seemed possible to get the print the way I wanted it. I had the right sky and a pleasing print of the stones. All that needed to be done was to put the two together. The separate prints of the sky and the stones were both printed with grade 4.5, but at different exposure times. The sky simply needed more exposure than the stones. Therefore, dodging the stones during a second exposure should do the trick. Nevertheless, this was not a simple task due to the complex skyline of the stones, and normal dodging would undoubtedly have left telltale signs. In cases like this, a customized dodging mask is called for.

I made another print, similar to the one shown in fig.2, being careful to make the whole skyline clearly visible and easy to identify. At this point, the stones were separated from the sky with the help of a very sharp knife, fig.4, creating the mask. Be extremely careful and make your fingers the first priority. Make the cut as precisely as you can. Trimming off too little and leaving the mask too big will partially cover the sky during the second exposure, creating a white line on the print. On the other hand, trim off too much and the stones will be doubly exposed, leaving an ugly black line. White lines are easy to get rid of. You can try to trim the mask a bit more if they are really big and obvious, or you can spot them in on the dry print if they are small enough. Avoid black lines, because they are there to stay. You can check the accuracy of the mask, fig.5, with one of the test prints.

Fig.6 shows the result of the two exposures using the mask. First, the whole print was exposed for 17.0 seconds at grade 4.5 to get the desired tonality for the stones. Then, the mask was registered on top of the print, using either the edge of the easel or the edge of the paper itself as a guide. A second exposure was given, this time for + 1 5/6 stops, or the difference in time required to get the sky to a 30.2 second exposure. You may have to experiment with the mask placement to minimize the telltale signs of the mask, but the results are usually worth the effort.

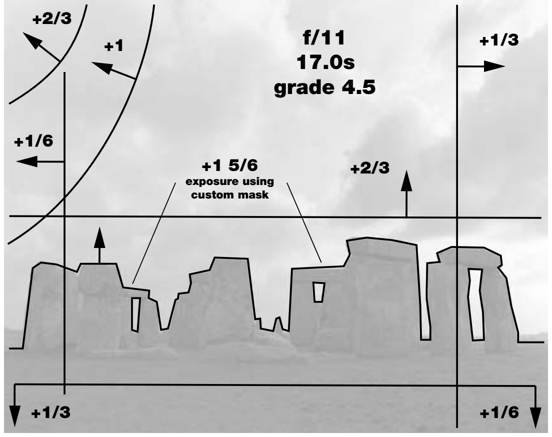


fig.7 The printing map records the basic exposure and all additional print manipulations. It might look rather complex at first sight, but in practice, it is a sequence of simple steps. The bottom edge burn is achieved by gradually pulling the burning card off the print from left to right.

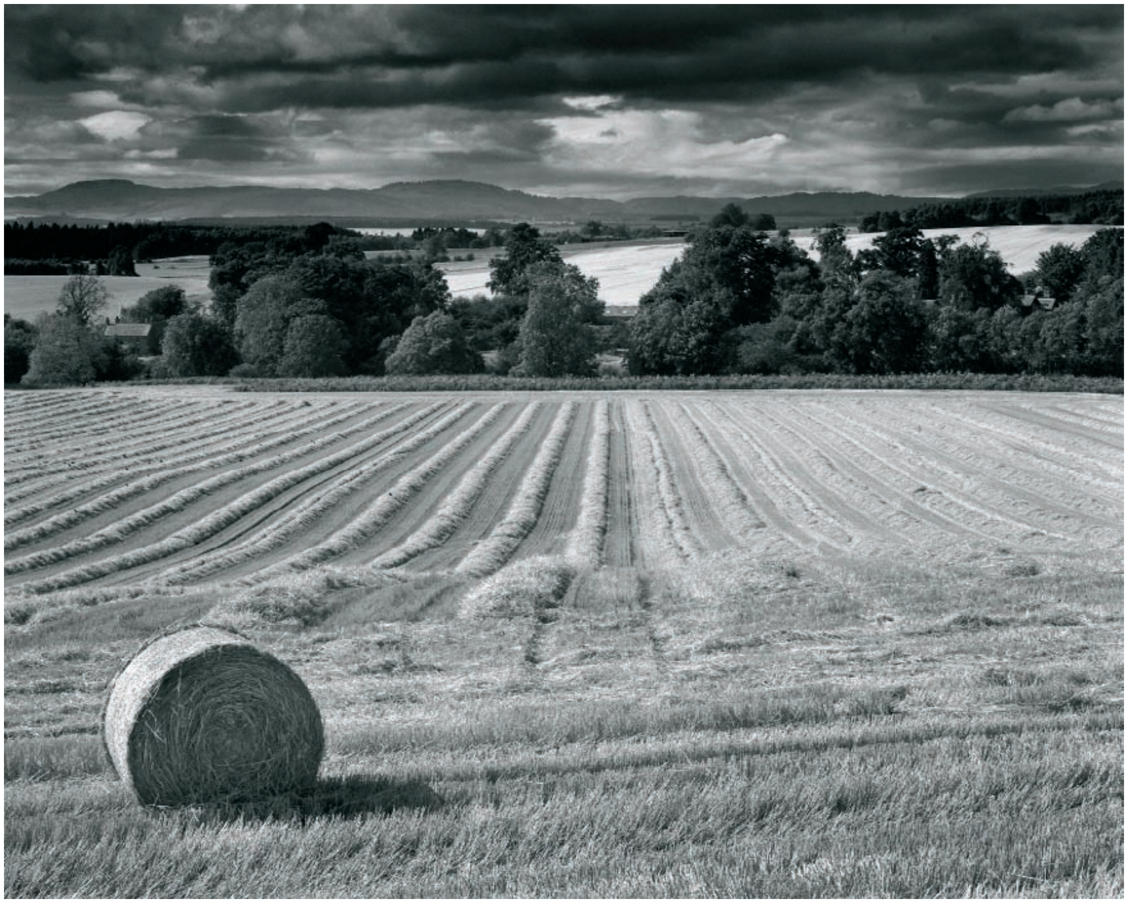
The leading image shows the final print. Additional burning down of the sky and some edge burning took place to maximize the impact of the scene (fig.7). There is little comparison to the straight print in fig.1, and this example clearly shows how much creativity is possible even after the image has been dedicated to film and the negative has been developed. Regardless of the time and effort spent to create an ideal negative, the creative process does not stop until the final print is committed to paper.

# Summer Storm

## The way I want to remember it

Scotland is well known for its beautiful landscape and harsh, rapidly changing weather conditions. My wife and I had already witnessed both, when we came to the end of a brief vacation there in August 2000. We decided to take the back roads that day, in hope of finding some interesting photographic subjects.

Near the small town of Balholmie, just north of Perth, I saw this field in the early afternoon. The farmer was in the process of collecting the hay bales, but for some reason one was left behind. A storm had gone through earlier, and the sun found an opening in the disappearing cloud pattern to illuminate the entire valley. The warm light and the simple lines of the scene intrigued me. Afraid to lose the light soon, I quickly set up the Toyo 45AX and mounted the Nikkor-W 210mm f/5.6 lens.



© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50066-1

The spotmeter measurements revealed a low overall subject brightness range and even less contrast in the foreground. I placed the shadows in the background trees on Zone III and marked the film for N+1 development to lift the field from Zone VI to Zone VII. An orange filter was used to increase tonal separation in the hay and brighten the field further. The stormy clouds added a lot to the atmosphere and a graduated neutral 0.6 density filter was added to darken the sky and increase this effect. I noticed that the highlight on the left of the hay bale would need some burning down, since it fell on Zone IX·5, but I preferred that to the danger of getting the image too soft. My normal EI for TMax-400 is 250, but it changes to 320 for N+1 development. Considering the orange filter, but ignoring the graduated filter since it affected the sky alone, I exposed at f/45 for 1/4 second. This was just in time, I might add, because the sun disappeared soon behind a thick cloud and the farmer came back to pick up the last bale of hay. The window of opportunity was less than half an hour long.

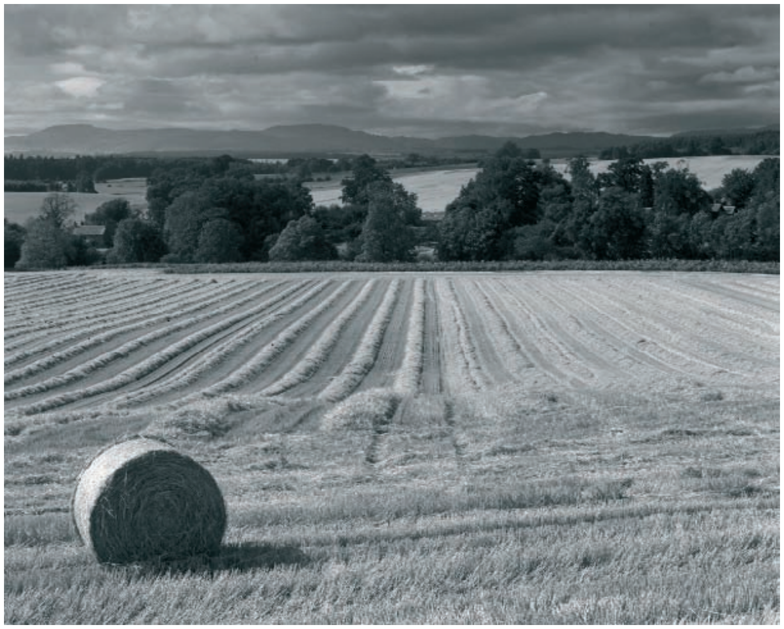


fig.1 (above) This is a straight print after following the electronic analyzer's recommendation.

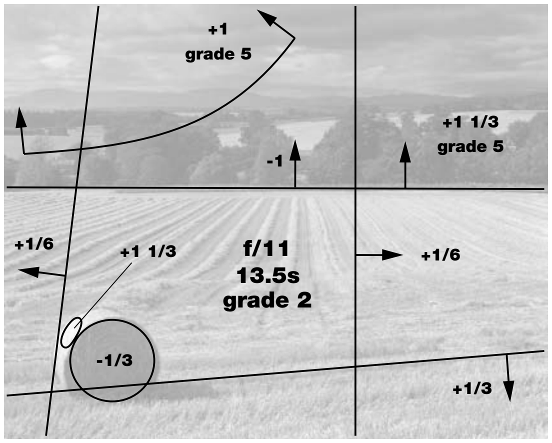


fig.2 (left) the final printing map after several test strip trials

Once in the darkroom, the electronic analyzer recommended a print exposure of 13.5 seconds and grade 1.5 to get started. Fig.1 shows the resulting print. This type of darkroom tool is highly operator dependent and relies on accurate calibration, but it can quickly get you onto 'first base'. In principle, a highlight and a shadow reading is taken, and the exposure is then determined from the highlight reading, and the contrast is calculated from the density range between highlight and shadow reading. In this case, the exposure was correct, but the print lacked impact and mood. In addition, the N+1 development had helped, but the print was not as I wanted to remember the scene.

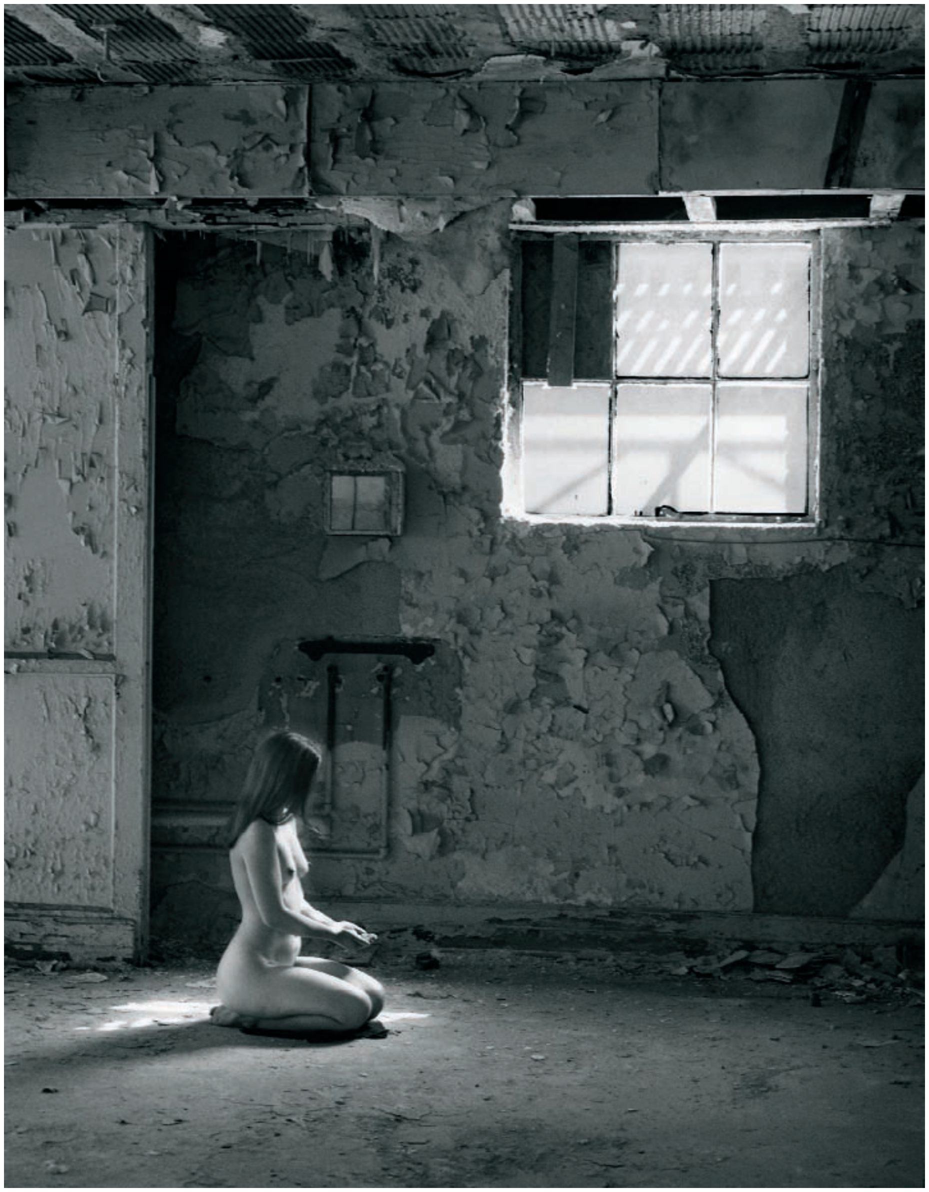
I tried a variety of test strips to alter the print appearance and finally decided on a print treatment, which is summed up in fig.2, the printing map. The main exposure is maintained, but the contrast has been raised to grade 2. During the main exposure, the shadow side of the hay bale was dodged for 1/3 stop to increase shadow detail. In addition, the entire background was dodged for a full stop or half the time. This was done with the intent to later burn it in at grade 5 for 1 1/3 stop. This partial split-grade printing will raise local contrast. But first, the highlight on the hay bale was burned-in for 1 1/3 stop at grade 2 to bring some detail into that area. Three edge-burns helped to keep the viewer's eye from drifting off the print. Finally, the left sky was unnaturally light, and another grade 5 burn for one stop gave a more evenly distributed sky.

The final print is conveying the light, which intrigued me in the first place. The sky is stormy and dramatic. The foreground has a warm glow and the simple lines of the field lead the viewer from the hay bale to the background.

# Toothpaste Factory

## Small detail helps to create a dramatic image

by Frank Andreae



Throughout the world, cities are filled with all sorts of buildings, both new and old. As a new building is created, it is photographed to show the latest architectural materials, efficiency of energy or majestic views of its surroundings. As the decades recede into the past, the buildings are transformed to meet new space requirements, torn down to make way for new structures, or simply left abandoned until such time when fate resurrects them again. At that point, the buildings are photographed to show where a new mall or parking lot will be built, or possibly, for a history book to save for new generations what once was.

The Ident Toothpaste Company abandoned its building in Detroit, Michigan USA in the 1960s. It was never torn down, but after all these years, there are tentative plans and demand to turn it into loft apartments. The peeling paint, rusting pipes, and vandalized interior add character and texture to the once bustling factory, full of workers and life. The multistory building stands empty now and makes a wonderful background for shooting environmental figure photography.

There are no working lights in the building, but fortunately, there are many windows on each floor to let the natural light flow across the space and upon the subject at hand. During the shoot, we experimented with a variety of poses at several locations throughout the building, working our way up from one floor to the next. On our way to the roof, we stopped on a floor that had fewer windows than most but more texture on the walls. Noticing the sunlight streaming through a smaller window, the model was placed in the light's path and cupped her hands as if trying to capture the rays. A light reading was taken through the auto prism of my Mamiya 645 Pro and double-checked with my Pentax Digital Spotmeter. Knowing that the window was many

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50067-3

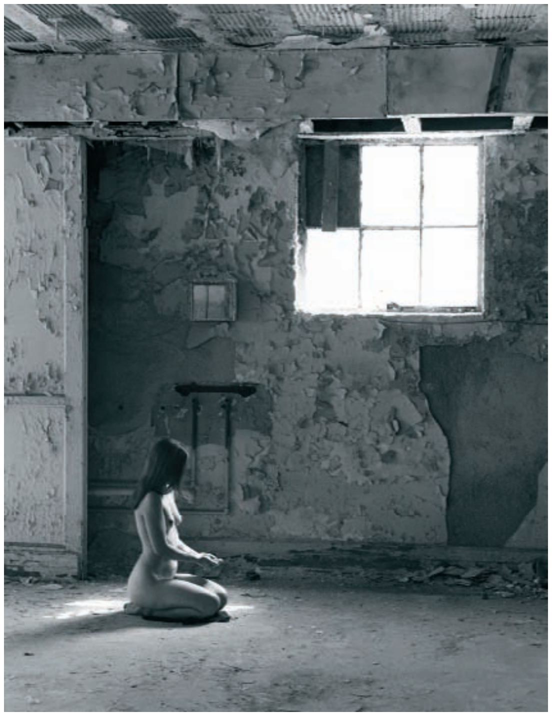


fig.1 (far left) The straight print shows no detail in the window, and the model does not appear to be as much the center of interest as is desired. The washed-out highlights of the window require additional exposure, and the model needs to be lightened to attract the viewer sooner.

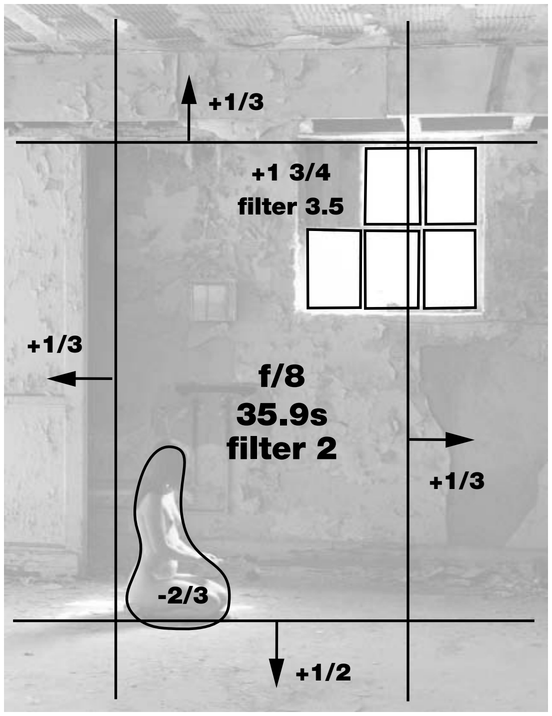


fig.2 (left) The printing map shows that a precise burn mask is needed to properly burn down the window area detail. The model is dodged during the base exposure, while the edges of the print are gradually burned down to give the image a more directed and dramatic feel.

stops of exposure greater than the wall, I exposed for the peeling paint and decided to burn in the window accordingly later in the darkroom. With TMax-400 film and a 100mm lens, an exposure of 1/8 second at f/8 was calculated.

With the film processed, dried and the contact print made, I realized that the composition captured the mood of the surroundings and assumed that the final print would be easily created. As I started doing test exposures, I determined a base time of 35.9 seconds with filter 2 for the entire print and dodged the model by 2/3 stop so she stood out more from the background. My initial test exposures on the window however, proved to be a little disheartening. I could see some detail on the negative, but for the amount of burning that was needed to show this detail, I was not able to hold a square hole above the print exactly as was necessary. I, therefore, proceeded to create a mask for this window by laying a piece of thick mat board on top of the printing easel and traced the image of the projected negative. I used a sharp utility knife to cut out just the five panes of glass, which were too bright, and left the window frames in place. The window now received a burn-in of 1 3/4 stops with filter 3.5 to show the detail of the scene outside. I applied an additional 1/3-stop burn-in to the top and the sides, while a 1/2-stop burn-in completed the image on the bottom.

This page intentionally left blank

# Part 3

# Odds and Ends

© 2006 by Ralph W. Lambrecht, all rights reserved

# Equipment and Facilities

This page intentionally left blank

# Image-Taking Equipment

## The photographer's tools of the trade

We both draw pleasure from making photographs with well-designed and well-maintained equipment. Between us, we have used at some time or other most 35mm, medium-format and large-format cameras, the makes and models of which are largely irrelevant. We do, however, have a few items that we both consider indispensable for capable and reliable picture making. What follows is an introduction to the fundamental tools, together with a discussion and some practical advice on equipment selection and testing.

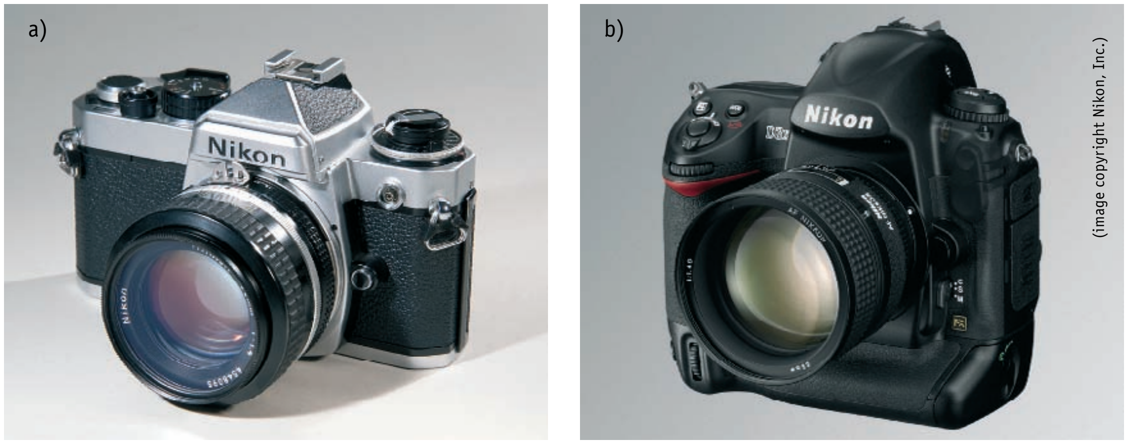
### Cameras and Film Formats

The camera is the most fundamental tool of every photographer. What started many centuries ago as a darkened room (camera obscura), simply providing an environment dark enough to observe a faint pinhole image, has turned into a rather sophisticated piece of image-taking equipment. As early as the 15th century, artists had substituted a small wooden box for the full-size room and later fitted it with a light-gathering lens (camera lucida). The inventors of photography simply replaced the copy screen of the camera lucida with a light-sensitive material to capture their images. Since then, modern cameras have matured to include a long list of features, which include the protection, accurate positioning and smooth transportation of film, firm attachments for fixed or exchangeable lenses, bright viewfinders for image composition, manual or automatic focusing aids, precise control of exposure time and/or lens aperture and sophisticated software to automatically calculate the 'optimum' exposure for each subject.

There are so many different cameras available today that it is often difficult to decide which camera to select for one's own photography. In this book, we limit our view to cameras that are likely to have the feature set and quality required by serious amateurs or professional fine-art photographers, well aware that it is impossible to make a meaningful camera recommendation without knowing the photographer's circumstances and photographic requirements. There is no such thing as one 'best' camera. The camera is a tool, and different photographic situations require

LEICA
M6
ELMARIT-M 1:2.8/24 ASPH.
LEICA

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50068-5



(image copyright Nikon, Inc.)

fig.1 The film-based Nikon FM (a) from 1977, the digital Nikon D3x (b) from 2008 and the rangefinder Leica M6 on the previous page are all examples of 35mm cameras. They are ideal for travel, reportage, news, sports and candid street photography, or any other area of photography where speed and portability are more important than ultimate image quality.

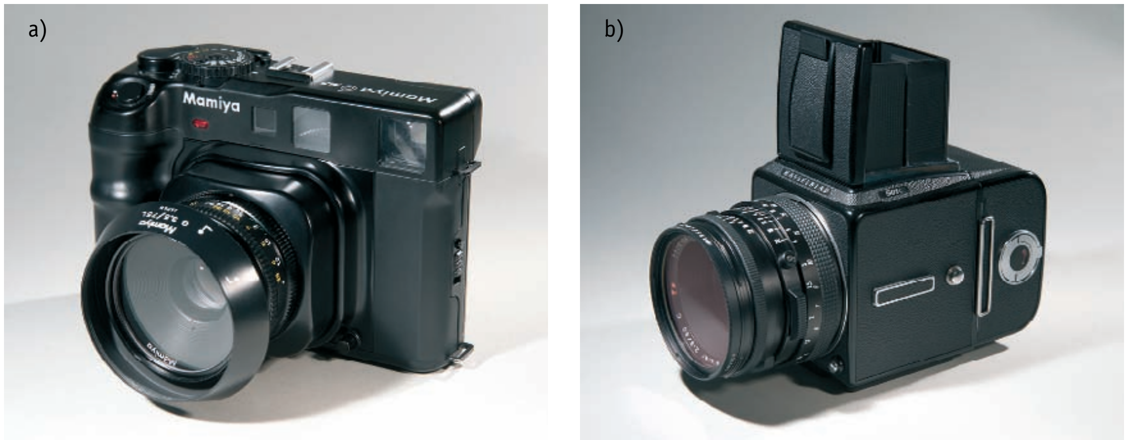


fig.2 The rangefinder Mamiya 6 and the Hasselblad 501C SLR are high-quality medium-format cameras. The Hasselblad is ideal for portrait, fashion and model photography, whereas the Mamiya is a good choice for the travelling photographer. Due to its retractable lens mount, the Mamiya does not need much more space than a 35mm SLR but offers the benefits of a medium-format negative.

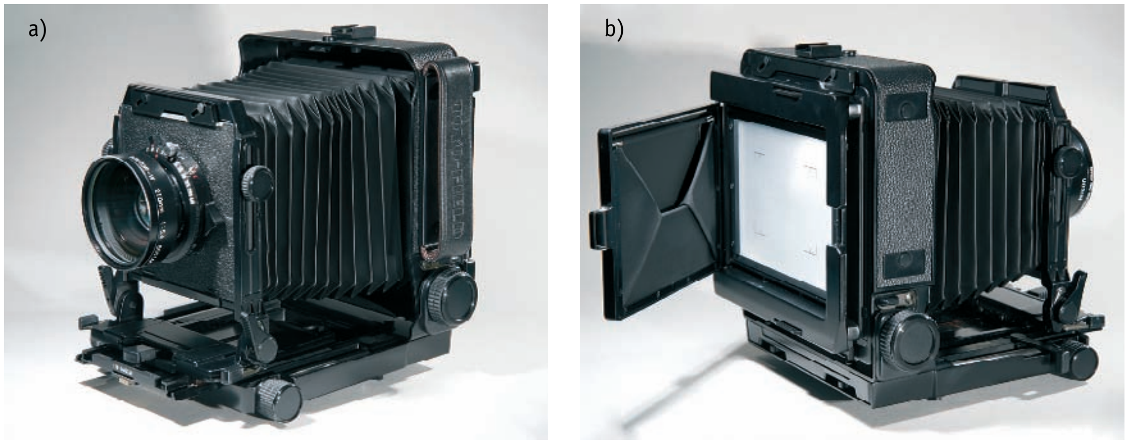


fig.3 The Toyo 4x5-inch metal-field view camera has the typical features of a large-format camera. Compared to the other cameras, large-format cameras are heavy, bulky and very rudimentary. At first glance, they seem like a remnant of the past, but a large-format camera is the ideal tool for architectural and landscape photography or whenever ultimate image quality cannot be compromised.

different tools. Nevertheless, one common way to narrow down the selection is to categorize cameras by their film format. Broadly speaking, there are three groups: small-, medium- and large-format cameras.

### Small-Format

All cameras that produce image sizes of up to 24x36 mm on 35mm roll film are small-format cameras (fig.1). The 35mm film format (fig.4) was initially created in 1892 as a motion picture film with an image size of 18x24 mm, and was adapted as early as 1908 for still cameras with an image size of 24x36 mm. Since the late 1960s, when it started to outsell 120 roll film, 35mm (FX) has been the world's most popular photographic film format. However, it took until the introduction of the first Leica in 1925 for the 24x36 mm format on 35mm roll film to reach global acceptance.

A modern high-quality 35mm lens has more resolving power than any other film-format lens, but the image quality of a 35mm negative is still limited by its small size. For example, to fill an 8x10-inch print without cropping requires an 8.5x enlargement, and such an enlargement will definitely reveal some non-image negative detail to the naked eye. On the other hand, due to the popularity of this film format, an enormous range of lenses and accessories is available for 35mm cameras, more than for any other film format.

The strengths of this format include its speed of operation, its versatility and its portability. All this makes the 35mm format a prime choice for travel, reportage, news, sports and candid street photography, or any other area of photography where speed and weight are more important than ultimate image quality.

### Medium-Format

All cameras that use 120 roll film are medium-format cameras (fig.2). Kodak introduced the 120 roll film in 1901 for the Brownie No.2, and it survives to this day as the most popular medium-format film ever. 120 roll film consists of the actual film material and a slightly wider and longer backing paper. The film is taped to the black backing paper at the leading edge, and together, they are wound onto a spool. The paper protects the emulsion from light and facilitates film transport and accurate negative spacing.

120 roll film is used for a variety of medium-formats, all limited by the film's width but varying in size along the film's length. The most popular medium-format negative sizes are shown in fig.4. Largely due to the increase in negative size, moving up from 35mm film to medium format improves image quality significantly. Most medium-format optics deliver excellent contrast and resolution, and the increase in negative size allows for much smaller enlargement to get to the same size print. For example, to fill an 8x10-inch print without cropping requires only about half the magnification of a 35mm negative, which will hide most non-image negative detail from the observer.

Medium-format cameras produce high-quality images without being too bulky or heavy. They are not as portable as 35mm cameras, and many are missing modern conveniences such as auto-focus and zoom lenses, while some are limited to only a few lens choices. However, medium-format cameras are a prime choice for portrait, fashion and model photography. Medium-format rangefinder cameras are also a good alternative for large-format landscape photographers, because the difference between a medium and a large-format print is often hard to tell.

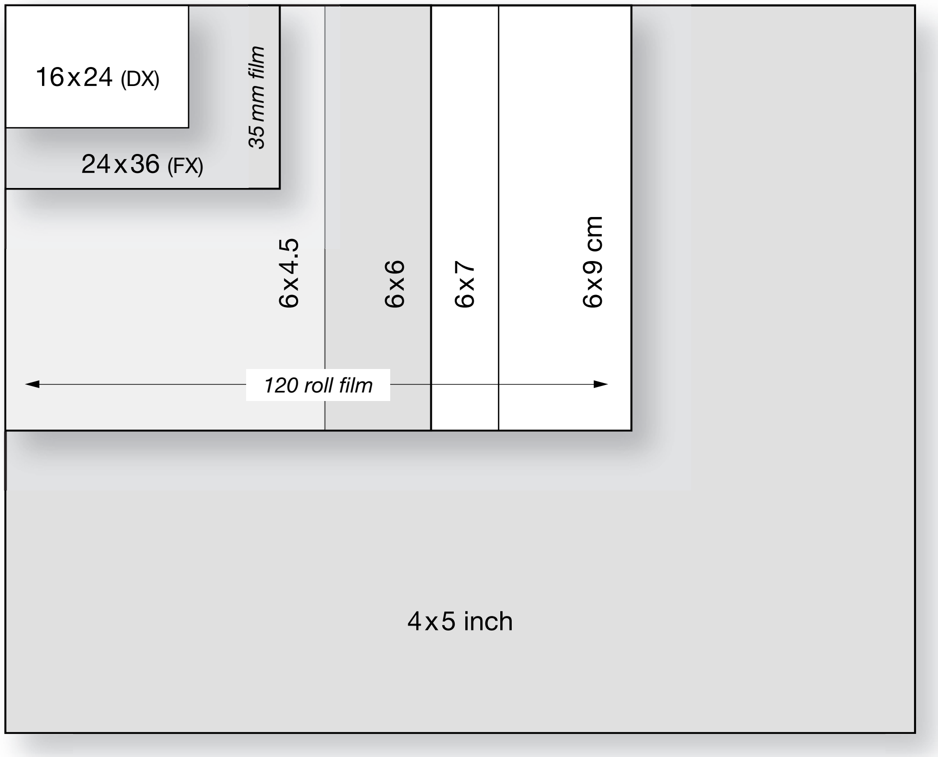


fig.4 Common film formats differ significantly in surface area. The larger the negative, the less enlargement is required to produce the same size print. When small negatives are enlarged 8x or more, non-image negative detail becomes obvious to the human eye, and print clarity is reduced. When it comes to image quality, there is no substitute for a large negative.

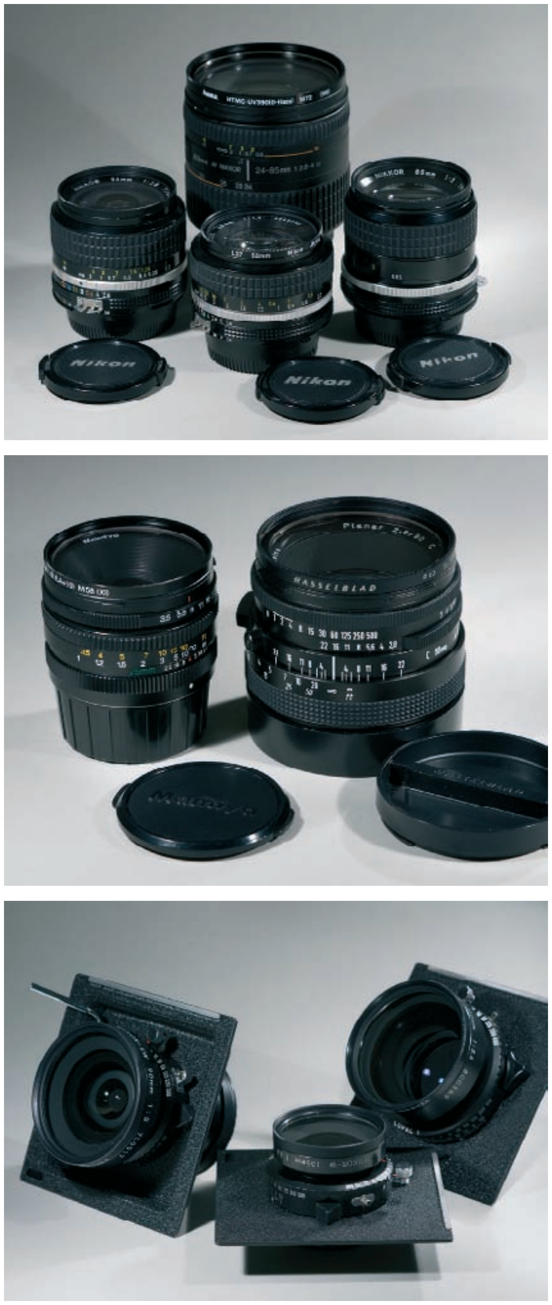


fig.5 Camera-lens designs differ with film format. (top) 35mm lenses are camera-brand dedicated and come as fixed-focal or zoom lenses. (center) Medium-format lenses are also dedicated to a camera brand, but zoom lenses are rare. (bottom) Large-format lenses are interchangeable between camera manufacturers.

### Large-Format

All view cameras that use 4x5-inch (or larger) sheet film are large-format cameras (fig.3). Large-format cameras have been around since the beginning of photography. The most common format is 4x5 inches (fig.4). Less common formats are 5x7, 8x10, 11x14, 16x20, and 20x24 inches. 4x5 cameras were very popular with press photographers until the mid 1940s, when more convenient medium-format and 35mm cameras became favored.

Compared to the other film formats, large-format cameras are heavy, bulky and very rudimentary. At first glance, they seem like a remnant of the past. A number of actions are required to take a single photograph: the camera must be set up on a tripod, a film holder must be loaded in the dark with single sheets of film, the scene must be composed on the camera's ground glass and the film holder must be fitted to the camera back prior to exposure. However, sometimes this is all well worth the effort, because large-format images are of exceptional quality. In addition, most large-format cameras have adjustable front and back standards, which allow for a better control of perspective and depth of field. A large-format camera is the ideal tool for architectural and landscape photography or wherever the very best image quality is required.

## Lenses, Shutters and Apertures

The image-creating capabilities of a photographic lens makes it the centerpiece of our image-taking equipment. Lenses demote everything else in our camera bag to the secondary role of merely supporting the photographic process. A photographic lens can be as simple as a tiny hole in a piece of metal foil that provides a fixed aperture for pinhole photography. Or, it can be as complex as a compound lens, made of a series of smoothly polished concave and convex pieces of specially coated glass to correct, as much as physically possible, the many optical aberrations that are inherent in a single lens.

Fig.5 shows a variety of advanced photographic lens designs for different film formats. Sophisticated 35mm lenses (top) come as fixed-focal or zoom lenses. They incorporate an iris diaphragm, providing an aperture adjustment mechanism, in 1/2 or 1-stop increments, and feature a manual or automatic cam system, sliding the lens elements into focus at any distance. Some 35mm lenses also include a leaf shutter, but in most 35mm cameras, timing the exposure is left to a focal-plane shutter in the camera body. Like 35mm lenses, most medium-format lenses (center) are dedicated to one brand of camera. Some incorporate a leaf shutter (Hasselblad 500 Series, right), others don't, because a focal-plane shutter is built into the camera body (Mamiya 6, left). The aperture ring is usually adjustable in 1/2 or 1-stop increments. Zoom and autofocus lenses are available for medium-format cameras, but they are not as common as they are for 35mm cameras. Large-format lenses have the benefit of being camera independent. One must take care that their image circle is large enough to illuminate the entire negative format, but any 4x5 lens will work on any 4x5 camera, by simply mounting the lens on a camera-dedicated lens plate. All large-format lenses have a built-in aperture diaphragm, adjustable in 1/3 stops, and are mounted into separately available leaf-shutters. There are no autofocus or zoom lenses available for large-format photography, but some lens designs allow modifying the focal length by simply replacing the rear lens element with another.

A list of typical lens-selection criteria includes focal length or range, maximum and minimum apertures, design, weight, advanced features, price and most importantly the optical quality of the lens. With modern lenses, the price is largely influenced by quality, but it also depends heavily on design complexity and advanced features, like autofocus or vibration reduction. As a general rule, lenses for rangefinder cameras are easier to design than lenses for SLRs, where the required packaging space for the mirror necessitates optical compromises. Consequently, rangefinder lenses are typically better than SLR lenses, which is especially true for wide-angle lenses. Similarly, fixed-focal lenses have a rather straightforward design, compared to zoom lenses, and are not as challenging to manufacture as their variable focal-length counterparts. They also typically have larger maximum apertures, and that's why many photographers still insist that their fixed-focal length lenses are of superior optical quality and have the edge over zoom lenses, in spite of advanced modern lens designs.

When working with fixed-focal lenses, it is sometimes difficult to pre-determine which focal length to choose for any given subject. Fig.6 illustrates a few visual clues to aid selection of the most appropriate focal length for any given subject, using only your

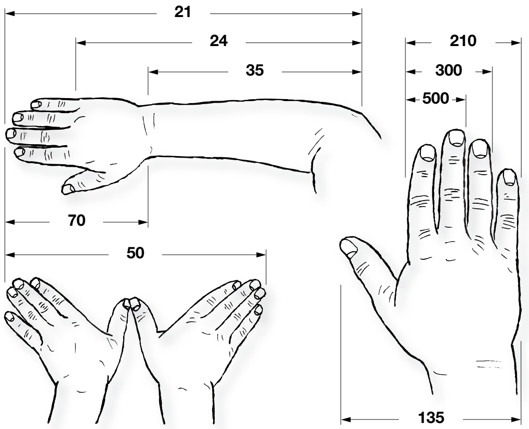
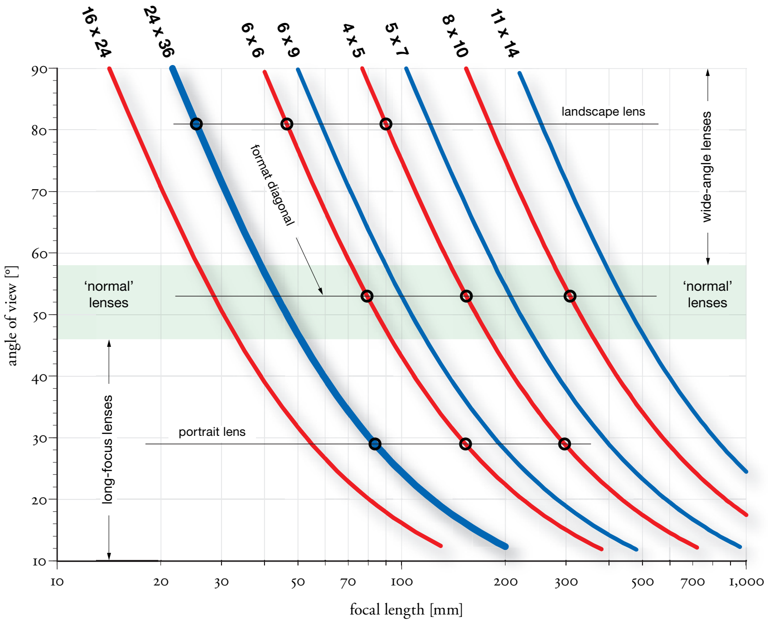


fig.6 This illustration gives a few visual clues to aid selection of the most appropriate focal length for any given subject, using only your arm and hands. The numerical values relate to 35mm focal lengths, when holding your hands at arm's length, or your arm as far away from your body as anatomically possible.



$$\alpha = 2 \cdot \arctan \frac{d}{2f}$$

fig.7 A 'normal' lens is specified as having a focal length roughly identical to the negative-format diagonal. This computes to about 80 mm for a 6x6 medium-format camera. The angle of view for a normal lens is independent of negative format, but the focal length, achieving the same angle of view, differs with negative format. The angle of view ($\alpha$) is given by the above equation, where 'd' is the dimension of the negative-format diagonal and 'f' is the focal length.

arm and hands. The numerical values relate to 35mm focal lengths, when holding your hands at arm's length, or your arm as far away from your body as anatomically possible.

Photographers working with different negative formats sometimes struggle to find the equivalent focal length of a known lens in another format. The angle of view is identical between negative formats, but the focal length, achieving the same angle of view, differs with negative format. A 'normal' (normal-focus) lens is specified as having an angle of view of about 50° or a focal length roughly identical to the negative-format diagonal. This computes to about 45 mm for a 35mm camera, about 80 mm for a 6x6 medium-format camera and 300 mm for an 8x10 large-format camera. Fig.7 illustrates the relationship between the angle of view and the focal lengths of different negative formats. It also provides a convenient way to compare focal length between negative formats. For example, if you prefer a 85mm lens for 35mm portrait work, you will get a similar effect using a 300mm lens with a 4x5 camera.

We usually trust that lens apertures, in conjunction with shutters, flawlessly control the total amount of light received by the film. It is easy to overlook the fallibility of shutter and aperture mechanisms, but their usage and age do affect their mechanical performance. Metal blades wear, springs weaken and lubricants become sticky, all causing unwanted deviations in exposure. Even electronically controlled mechanism activation does not guarantee perfect performance forever. We must accept that the intricate mechanisms of lens apertures and shutters are subject to a certain amount of mechanical error.

### Shutter Accuracy

With long exposures above 1 second, shutter accuracy is less significant to film exposure than film reciprocity failure. At the other timing extreme, fast shutter speeds push the mechanics to the limits of their capabilities, and here, even small inaccuracies become a significant cause for exposure errors.

The mechanics of a shutter are affected by extreme temperatures. In cold conditions, shutter lubricants

fig.8 Electronic shutter testers can be used to measure the effective shutter speeds of leaf and focal-plane shutters. Knowing the true shutter speed, the photographer can make the appropriate exposure adjustments, as long as the error is consistent and repeatable.

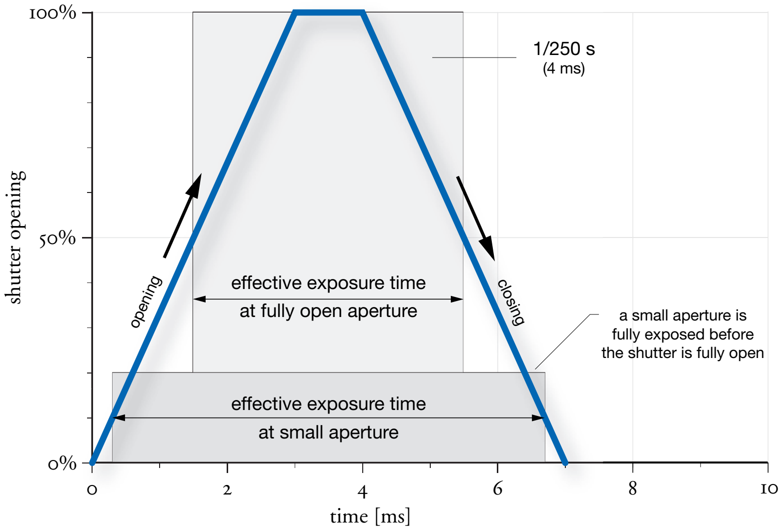


fig.9 Exposure starts as soon as the leaf shutter opens with a faint image and gets increasingly brighter until the shutter is open. The reverse takes place as the shutter closes. The exposure time marked on the shutter is the time from when the shutter is half open until it is half closed. The exposure contribution of an opening and closing shutter is minute at slow shutter speeds, but becomes significant at fast speeds, making for accurate exposure at wide-open aperture.

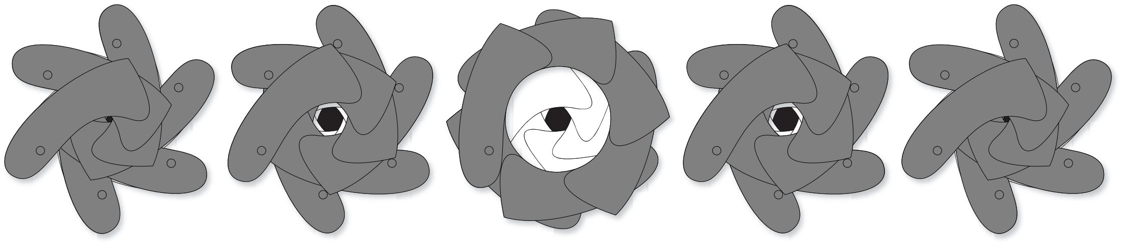


fig.10 A leaf shutter in combination with a small aperture and fast shutter speed increases effective exposure significantly. A small aperture hole is completely revealed by the shutter almost as soon as it opens and provides unobstructed exposure until just before it is fully closed. Consequently, as the aperture is made smaller, the effective exposure time becomes longer than the marked exposure time.

become more viscous. This affects the shutter speed accuracy. The mechanism moves more slowly, causing overexposure. Working the shutter a few times before making an exposure will free up the mechanism and reduce the error. This technique is also helpful to improve the performance of shutters that have not been used for some time. Warm temperatures have the opposite effect with faster moving mechanics causing underexposure.

Thanks to modern electronics, shutter errors can be detected with test equipment similar to the shutter tester in fig.8. Shutter testers can be used to measure the effective shutter speeds of leaf and focal-plane shutters. This simple low-cost shutter tester was once sold by Calumet Photographic but is no longer available as new. Expensive professional models are still on the market, but at a price often beyond the average amateur's budget. However, their functionality is based on the same technical principle, in which a light sensor triggers a digital counter as soon as the light level reaches a certain level. Alternatively, consult a good camera repair shop to have your shutters tested, or if you're handy with electronic circuitry, take a look at the chapter 'Make Your Own Shutter Tester' for simple do-it-yourself instructions. Knowing the true shutter speed, the photographer can make the appropriate exposure adjustments, as long as the error is consistent and repeatable, but the equipment should be serviced by an authorized source for convenience or if errors are erratic and inconsistent.

Apart from mechanical errors, the effective exposure time of a leaf shutter, in combination with a small aperture and fast shutter speed, is significantly different from the marked exposure time. This can be explained by the interaction of the shutter and aperture. Prior to the exposure, the lens aperture blades are set to a fixed position providing an opening for the image forming light. At this point, the metal blades of the leaf shutter are blocking the light from entering. At the beginning of the exposure, the shutter blades open rapidly within 2-3 ms, but when the exposure is completed, they close just as quickly. Of course, film exposure starts as soon as the leaf shutter opens. Nevertheless, since leaf-shutter blades are very similar in construction to aperture diaphragm blades, the exposure starts with a faint image and gets increasingly brighter until the shutter is wide open. The reverse takes place as the shutter closes. To account for the exposure during opening and closing of the shutter, the exposure time marked on the shutter is the time from when the shutter is half open until it is half closed. Hence, the shutter is not marked with the total exposure time but with the effective exposure time. The exposure contribution of an opening and closing shutter is minute at slow shutter speeds, but becomes significant at fast speeds. Working with the effective exposure time, rather than total exposure time, makes for a more accurate exposure at wide-open apertures.

However, if a small aperture was chosen, the effective exposure time will be longer than expected. Figures 9 and 10 illustrate this unavoidable exposure error. A small aperture hole is completely revealed by the shutter almost as soon as it opens and just before it is fully closed. Consequently, as the shutter speed is increased and the aperture is made smaller, the

$$2^{EV} = \frac{N^2}{t}$$

$$E = \frac{C}{ASA} \cdot 2^{EV} \qquad [lux]$$

$$L = \frac{K}{ASA} \cdot 2^{EV} \qquad \left[\frac{cd}{m^2}\right]$$

Photometric values for illumination 'E' and lumination 'L' can be calculated from any lightmeter measurement (aperture 'N' and exposure time 't', or the exposure value 'EV') as long as the meter's calibration constants for incident 'C' and reflected 'K' readings are known. Typical values range from 250-280 for 'C' and 12-15 for 'K', but individual values must be obtained from the manufacturer.

effective exposure time becomes increasingly longer than the marked exposure time. This is particularly true of large-format lenses where apertures smaller than f/22 are common and exposure errors can be up to 1 stop. Luckily, the combination of fast shutter speeds and small apertures don't occur very often in practical image making.

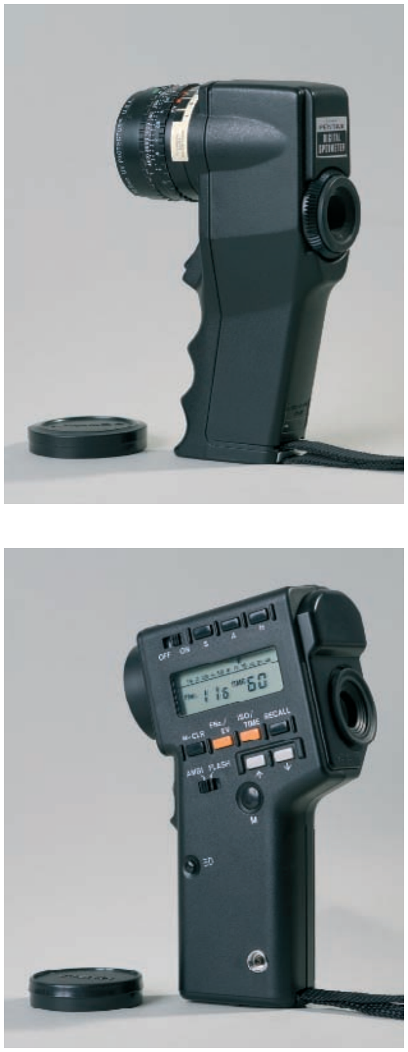


fig.11 Dedicated spotmeters are optimized for serious Zone System work. The Pentax Digital Spotmeter measures ambient, and the Minolta Spotmeter F both ambient and flashlight.

**Aperture Accuracy**

The lens aperture is a mechanical device, even when controlled by electronics. Aperture errors are caused by mechanical tolerances and sticky mechanisms. Like shutters, they are most likely to perform sluggishly in cold conditions and after long periods of non-use. In this case, work the aperture blades a few times before making the actual exposure.

Sticky aperture mechanisms also affect modern SLR cameras, which abruptly close the aperture to the set value before opening the shutter. If the diaphragm blades are unable to reach the chosen aperture in time, the opening will be larger than indicated when the shutter fires, causing overexposure.

It is possible to detect some defects by observation. With the camera facing you and using the stop down lever, close the aperture to its minimum setting. Inspect the opening, try to memorize its diameter and compare it to its closed size when firing the shutter, over a range of shutter speeds. The diaphragm should close to the same aperture in every case. If the camera is likely to be used in cold climate conditions, conduct the test outdoors on a cold day and with a cold camera. Any oil or grease on the diaphragm blades should be serviced at once.

In addition to the mechanical issues, maximum aperture extremes are often advertised with optimistic aperture values and provide uneven illumination, which ultimately leads to objectionable vignetting. The minimum aperture accuracy is more sensitive to mechanical tolerances. For these reasons, it is wise to avoid using extreme apertures and fast shutter speeds for material testing, even with cameras that have focal-plane shutters.

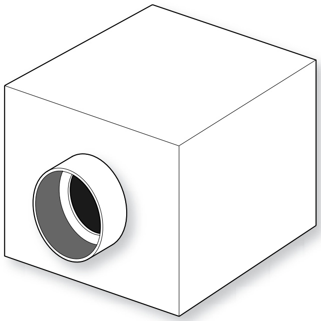


fig.12 The self-made flare test-box is painted bright white on the outside and flat black inside. The shaded opening provides a photographic 'black hole'.

## Lightmeters

Lightmeters are divided into two main categories, 'reflected' and 'incident' meters. A reflected lightmeter is designed to measure the light reflected from the subject, which is referred to as lumination. An incident lightmeter measures the light falling on the subject, which is illumination.

Some reflected lightmeters simply average all measurements from the full field of view, others give priority to the center or perform sophisticated, subject-dependent computations to propose the best film exposure. Another option is to use a dedicated spotmeter (fig.11), reading luminance only from a small area.

To use the Zone System seriously, a spotmeter is essential for measuring selected exposure values. Ideally, the meter should have a field of view of no more than 1° and a resolution of 1/3 stop or better. The models we have tried, which include those by Gossen, Minolta, Pentax and Sekonic, all have a unique color response, calibration and resistance to flare, making an overall recommendation more one of personal choice. Ralph prefers the Minolta meter for its fine resolution and the Pentax meter for its simplicity, Chris prefers the multi-functional Sekonic, since it measures reflected and incident light with ambient and flashlight.

Whichever meter you own, it will take some time to understand its limitations and obtain reliable exposure indications in a variety of situations. Accuracy is difficult to assess, but the color response and the meter's resistance to flare can be evaluated quite easily. The chapter on film exposure discusses film and meter color sensitivity and the application of filters, to compensate for differences between the perceived and recorded subject brightness of different colored objects.

**Flare Testing**

In a perfect world, one should be able to measure small shadow areas without interference from adjacent light sources or bright white surfaces. Spotmeters are not perfect and, like cameras and lenses, suffer from flare. Flare can be crudely evaluated by measuring and exposing a photographic 'black hole' in close proximity to a bright white surface. A simple self-made box or a modified shoebox will suffice as a test target (fig.12). Take the box and paint the outside bright white and the inside flat black. Then, cut a 50mm (2-inch) hole into one side of the box and construct a shade, protecting the hole from direct light. Paint the inside of the shade flat black as well. Some light will still enter the box, and an extremely small fraction of it will be reflected back through the hole but not enough to create any density in the negative. We have successfully created a perfect 'black hole'.

To estimate flare, place the box in daylight, with the black hole facing spotmeter and camera. Then, take an exposure reading of the hole from about 2.5 meters (8 feet), making sure that the spotmeter's measuring area is entirely within the black hole. Any reading above the meter's minimum is a measure of the flare generated inside the meter. Now, take an incident reading at the box and expose a piece of film accordingly. Any negative density in the hole is due to camera and lens flare, because the black hole does not provide any image-based exposure. Ideally, meter and camera flare should match, but if required, flare can be minimized by shielding meter and camera lens from any direct light source with the palm of your hand.

### Incident Meters

An incident meter measures the light falling on the subject, averaging out all involved light sources and largely ignoring subject luminance (fig.13). Consequently, the reading of an incident meter is not influenced by subject brightness. For example, the reading due to bright sunlight falling on a dark barn door is identical to the same light falling on a white horse. Both subjects require the same exposure, for the barn door to appear as dark and the horse to appear as white as they really are. As long as the subject brightness range and the distribution are about normal, incident readings are simple, fast and accurate. Not surprisingly, that's why incident meters are so popular with studio photographers.

Not much is published about using incident light meters for the Zone System, but they are a practical alternative to spotmeters in typical outdoor scenes. Their application relies on the fact that natural objects have an average subject reflectance range of about 5 stops. In other words, in perfectly diffuse lighting, a natural scene has a subject brightness range of about 5 stops. Consequently, we only need to know how the subject lighting ratio deviates from '0', in order to determine the appropriate development scheme.

Two incident-meter readings, always pointing the meter's dome towards the camera, are enough to determine Zone-System exposure and development time. First, take an incident reading in a shadow area of the subject, or shade it from the dominant light source. Note the reading, because it gives a literal rendition of the shadow-tone values and dictates the exposure. Take another reading in a brightly illuminated area of the subject, or expose it to the dominant light source. The difference between these two readings is a measure of the subject lighting ratio in stops.

The actual subject brightness range is the sum of the average natural subject reflectance range (5 stops) and the measured subject lighting ratio. Since we define a normal scene as having a 7-stop subject brightness range (pictorial range), a subject lighting ratio of 2 stop requires normal processing (N), 3 stops require N-1, 4 stops N-2 and so on. If the subject lighting is perfectly diffuse (no difference between the two readings), N+2 development is required in order to increase the negative contrast to the pictorial range.

## Tripods, Heads and Plates

For architecture, landscape and studio photography, a decent camera support is essential. In most cases, any tripod is better than none, but one should choose with care and consideration between the many brands and designs available. Furthermore, the choice of tripod head is as important as the tripod itself, and it is often beneficial to mix and match designs regardless of manufacturer. Additionally, the choice of materials contributes to the final performance, and often a deciding factor is transportability. No tripod is less rigid than the one left at home, because it was too heavy.

We have used many brand-name tripod models between us, in a variety of materials and styles, from traditional aluminum models to modern carbon-fiber composite designs. Each model had its pros and cons. No design is optimal in every situation. Consider your photographic needs before you decide on a tripod, based on weight, size, working height, operation speed or rigidity.

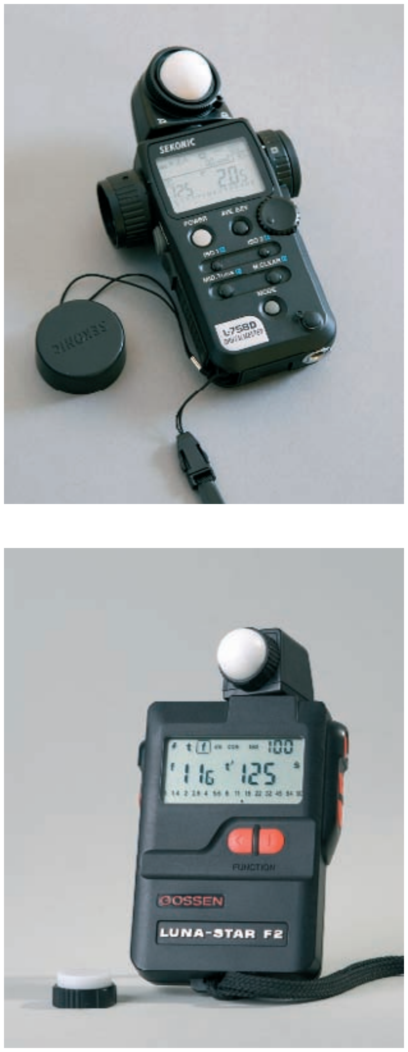


fig.13 Incident meters are invaluable, especially in studio conditions. Both meters, shown here, measure ambient and flashlight. The Sekonic L-758D is also waterproof and features an integrated 1° spotmeter, making it a universal meter for field and studio work. In the absence of an incident meter, a reflectance reading off of a Kodak Gray Card will yield the same result.

Ralph prefers the traditional Manfrotto aluminum designs for their solid support in the field, and selected a professional studio stand for his indoor work (fig.14). Chris is more weight conscious and settled on two Gitzo carbon-fiber tripods (fig.15) instead of the aluminum models. These are incredibly light yet surprisingly rigid. Although carbon fiber is less robust than aluminum, with a little respect, it is fine for everyday use. The tubular carbon-fiber leg-and-clamp design also has remarkable vibration-damping properties. Chris favors two sizes, a large, 3-section version for studio and large-format work and a shorter, 4-section model for field trips with a 35mm or medium-format rangefinder camera. The larger model is modular, accepting a range of center-column styles with the option of dispensing with the column altogether for lightness and ultimate rigidity.

With any design, it is good practice to increase the height of the tripod by extending the legs, before raising the center column. This increases the tripod's footprint and, consequently, its stability. Tripod stability is further increased by adding weights to lower column, legs or braces. A lightweight option is a rubber foot strap, which is attached to the lower column and simply stepped on during exposure.

**Tripod Heads**

Each material and joint in a tripod system affects the rigidity of the whole. The tripod head, often chosen for convenience, is arguably the most critical component in the tripod system. It is wise to evaluate models from other brands, since most use a standard 3/8 or 1/4-inch fixing thread. There are two main designs (see fig.16): ball-and-socket (B&S) and pan-and-tilt (P&T). Ralph uses P&T designs exclusively. Chris typically uses B&S heads for fieldwork and P&T heads for studio work. Each has been carefully chosen to ensure maximum rigidity through a combination of close tolerances, large contact surfaces and a low profile. Most heads are made from aluminum or

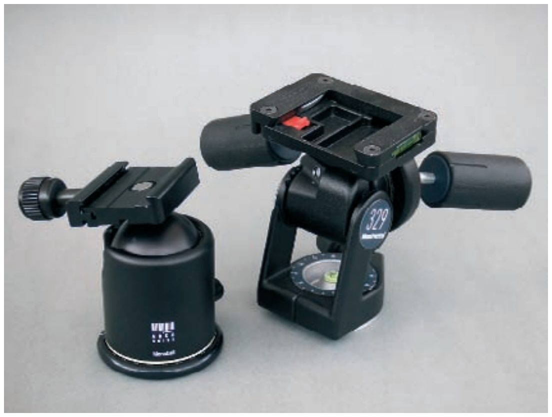
fig.14 (top) A professional studio stand can handle all film formats and more than one camera at once.

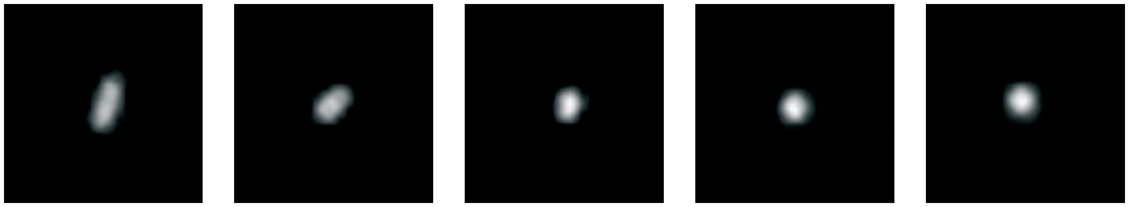
fig.15 (right) A rigid tripod serves most needs, from large-format studio work to fieldwork with smaller formats.

fig.16 (top right) The Arca Swiss ball-and-socket model is substantial enough for lightweight large-format cameras and is smooth and quick to operate. The traditional Manfrotto pan-and-tilt head is 550g heavier, with the strength for special applications, heavy loads and ultimate stability.

fig.17 (bottom right) The two Arca Swiss plates have bare aluminum bases and form a perfect mate to smooth bottomed cameras. The two Manfrotto plates are supplied with a soft rubber or cork mat. The smaller plate has had its mat changed to hard leather to reduce the compliance between camera and tripod.

GITZO
GITZO





1/60 s
50mm lens, handheld

1/125 s

1/250 s

1/500 s

1/60 s
tripod-mounted

fig.18 To get the highest resolution possible, the use of a tripod is essential, and the rule-of-thumb, requiring nothing less than the reciprocal of the focal length as the maximum exposure time, is inadequate. Shown here, from left to right, are the results of photographing a point light source, at a distance of 5 m, with a handheld 50mm lens, at 1/60, 1/125, 1/250 and 1/500 of a second. The suggested time of 1/60 s is far from adequate. It took as little as 1/500 s to eliminate camera shake completely. But, the tripod-mounted camera delivered a perfect result at 1/60 of a second.

magnesium alloy. Even though these materials are stiff, each arm, platform and bracket must be as short as possible to prevent a 'spring-back effect' under load. For instance, the otherwise versatile, off-center B&S heads are not ideal for medium-format or heavier cameras, in our opinion.

By design, a B&S head is at its optimum when the weight is directly above the pivot. Arca Swiss and other manufacturers have also realized that larger balls improve rigidity, especially in a tilted position. Their range of close tolerance B&S designs are world renown, and its progressive friction control is particularly welcome when manipulating an unwieldy camera.

### Camera Plates

Last, but by no means least, is the method of camera attachment, called camera plates (see fig.17). Those varieties that rotate the support platform against the camera base are best avoided. They inevitably create scratches and, more importantly, may not grip sufficiently, especially if the camera base is not perfectly smooth. Our favored tripod heads use a separate quick-release camera plate, which is tightened to the camera base by means of a thumb wheel or coin-slotted screw head and then securely fastened or clipped to the head. This not only allows the photographer to change cameras quickly, but in the case of the many camera designs, it allows the photographer to use custom designed camera plates to prevent swiveling, avoid covering rewind buttons and to maximize the supported camera base area.

### Soft Is Bad, Hard Is Good

Clearly, when it comes to tripod and head design, rigidity is important; yet, many camera plates are topped with a soft textured rubber or cork material, to grip and protect the camera base. A small improvement can be obtained when this is replaced with something less compliant, to increase rigidity and reduce nose-droop, especially on the smaller plates designed for SLRs. If your camera has a flat base, the best interface material is bare metal, but if the camera has to be used in a tilted position, a base-plate with a small anti-twist ridge or pin, like the middle camera plate in fig.17, solves the issue effectively, without the need for excessive tightening of the fixing screw. For those cameras with uneven bases (the Mamiya 6 and 7 have raised bumps on their base around the tripod bush), a little compliance prevents stressing the camera base-plate. A piece of hard leather, a scrap piece or an old coaster cut to size, is ideal and provides just enough give.

The effectiveness of a rigid camera support may be substantiated with a simple test. For the test sequence shown in fig.18, a 35mm SLR, fitted with a standard 50mm lens, was used to photograph a point light source from a 5m distance. A range of handheld shutter speeds is compared to a slow-speed tripod-mounted exposure. Contrary to common belief, it is impossible to get the best from our lenses unless a very short exposure or a solid tripod is used. It is pointless to mount premium glass on the front of the camera, unless similar care is taken with the camera support.

## Flash Units May Harm Your Camera

Some photographers prefer to use available daylight exclusively and enjoy, for example, the beauty of a natural window light. Others would rather have the control and flexibility available from artificial lighting, which allows them to precisely model each lighting situation themselves. The trouble with available light is that it is not always available, or there is just not enough of it. Artificial lighting and flash units offer a creative alternative.

Flash lighting can be as simple as a small pocket flash gun or as elaborate as an entire studio lighting setup (see fig.19), but both pose the same potential

HENSEL
performing light
Porty

fig.19 The trouble with available light is that it is not always available, or there is just not enough of it. Artificial lighting and flash units offer a creative alternative, but be careful, not every flash is as sensitive to your camera as this portable unit is from Hensel.
(image copyright Hensel, GmbH)

danger to the electrical contacts that trigger the flash synchronization in cameras, lenses or shutters. According to ISO 10330:1992, all cameras are designed to accept trigger voltages of up to 24 volt. There are two compounding problems, however. Some cameras just cannot handle trigger voltages that high, and many flash units produce much higher voltages. The result is unexpected wear of the electrical contacts, or worse, a 'fried' camera, lens or shutter. Fortunately, the remedy is quite simple: Don't attach flash units directly to your camera! Use a wireless radio flash trigger, consisting of a sender and receiver, for the first flash unit (fig.20a), and fire additional units with optical flash triggers or so-called 'slaves' (fig.20b).

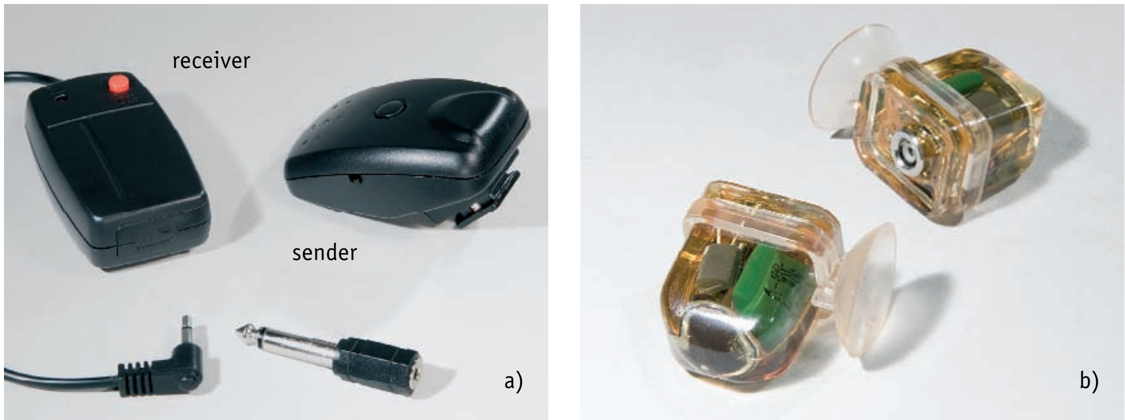
## Quality, Accuracy and Resolution

It is worth considering that many purchases are made on the promise of quality and accuracy. The concept of quality is the combination of performing within design specifications and satisfying customer expectations. On the other hand, accuracy is the ability to perform with precision compared to a known standard. Both concepts are difficult to measure without specialized equipment, which requires certified calibration in regular intervals. Brand name and product price alone are no guarantee for accuracy, but a practical photographer is more interested in repeatability and resolution than absolute accuracy anyway.

The repeatability of camera, meter or darkroom equipment is perhaps the most important, as it enables the individual to make meaningful long-term use of their equipment, inviting comparison and consistency. The variation from day to day, or frame to frame can be measured using simple techniques. For example, an exposure of a test target taken outdoors on a cold day with cold equipment can be compared with that on the next frame taken with pre-warmed equipment.

Resolution is often advertised as an indicator of accuracy, but that is not necessarily the case. Resolution, within the context of this chapter, simply refers to the fineness of a meter reading, or the control over a shutter or an aperture setting. A meter with a resolution of 1/10 stop, but poorly adjusted, may be less accurate than one with 1/3-stop resolution that performs within manufacturing tolerances. For this reason, it is worth having your equipment checked periodically by a reliable source. This is especially true for meters and shutters.

fig.20 A wireless radio flash trigger (a) is the safest way to trigger flash units regardless of size. The sender is directly attached to the camera, lens or shutter, and the receiver is connected to the first flash unit. Additional flash units can be fired with optical flash triggers (b) or so-called 'slaves'. This way, high trigger voltages from the flash unit cannot harm the sensitive electrical contacts of the flash synchronization.



# Darkroom Design

## Creating a practical and creative environment

Since publishing the previous edition, we have both changed our darkrooms in an attempt to improve the balance between domesticity and dedication. Together, we have designed and worked in about a dozen darkrooms over the years, always implementing the lessons learned from one design into the next. In this chapter, we highlight the basics of darkroom design and draw upon our personal experiences and solutions to address common issues.

Individual darkroom designs differ with photographic requirements, available floor space and frequency of use. Blending the darkroom into a domestic environment can be a challenge, but if designed well, it can be a haven from the perpetual demands of everyday life. On the other hand, an impractical and uncomfortable darkroom will not provide the creative atmosphere necessary to create a fine print.

### The Room

All you need to set up a darkroom is a spare room or bit of available floor space. The basement is an ideal location as long as it has adequate ceiling height, because this area of the house experiences only minimal seasonal temperature fluctuations and typically offers easy access to heating, electricity and plumbing. Looking at the same criteria, attics and garages are less attractive candidates. The minimum floor-space requirements for a darkroom differ depending on maximum print size and printing equipment. Fig.1 and 2 illustrate two darkroom layouts, both designed to create prints up to 16x20 inches. The medium-size darkroom in fig.1 has separate dry and wet areas, and offers enough room for five trays as well as a large worktop. In fig.2, a vertical slot processor makes it possible to reduce darkroom dimensions to a minimum.

© 2000 by Steve Sherman, all rights reserved

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50069-7

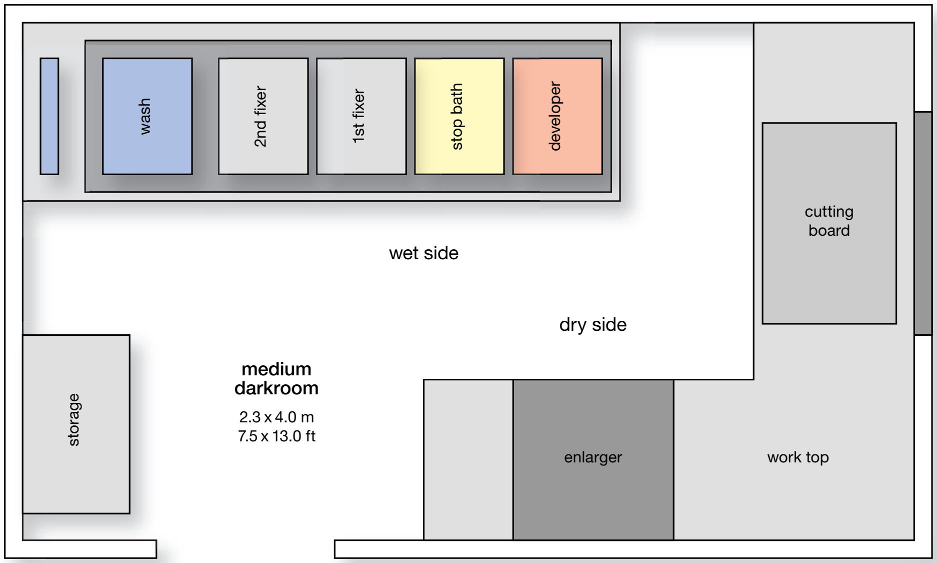


fig.1 This medium-size darkroom has separate dry and wet areas, and offers enough room for five 16x20-inch trays as well as a large worktop.

## Light Proofing

After an appropriate location for the new darkroom has been found, it must be completely shielded from external light sources to make the room totally dark. Initially, doors will be your main focus, because they must be light proofed while maintaining their intended functionality. Next come the windows, followed by air vents, suspended ceilings and any other potential sources of unwanted light. Continue until the last minute crack in the walls is plugged, and the room is completely lightproof.

### Doors

Large club, community or commercial darkrooms must meet the need for people to freely move in and out of the room during the darkroom session without external light entering the room. This is why these darkrooms are typically fitted with revolving doors or an interlocking double-door system.

Given sufficient floor space, an open, light-trapping entrance is a more convenient alternative and costs less. The custom-built example in fig.3 provides easy room access without interrupting ongoing darkroom sessions for others. The inside walls of the light-trap are painted flat black, and an optional set of light curtains provides extra protection if the darkroom entry is exposed to bright daylight.

However, for a domestic darkroom with single-user access and limited floor space, all you need is an effective way to light proof the existing door. We recommend sticking to the principles of light trapping and staying away from foam or rubber seals. A good solution is shown in fig.4. Fig.4a&b illustrate the problem, and fig.4c&d present a solution. All light-leaks from the door surround were eliminated by attaching a thin wood frame to the door panel, mounting a wooden board to the floor, and painting all surfaces where light could pass with a flat-black paint. This traps more light than regular foam seals, is more durable and does not add to the door closing effort. Add a bit of opaque tape over one side of the keyhole, and the door is completely lightproof, but still fully functional.

### Windows

Often, the easiest solution to eliminate any light coming in through the windows is to board them up permanently. However, if at all possible, light proof all windows without eliminating easy access to their opening mechanisms. Then, you can still open the

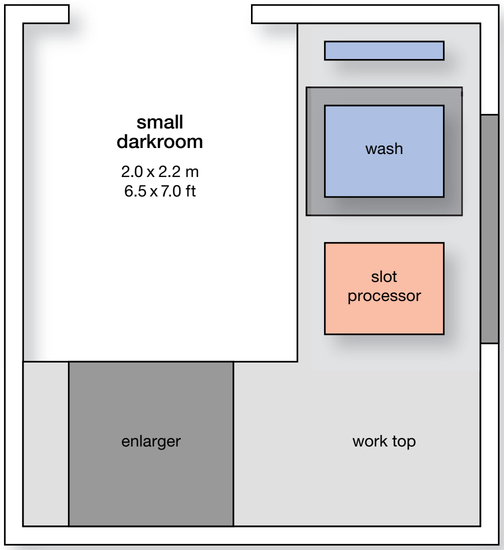


fig.2 A vertical slot processor makes it possible to reduce darkroom dimensions to a minimum, yet it can produce prints up to 16x20 inches.

windows to air out the darkroom after a long printing session or during a smelly toning session, when you do not necessarily need the dark environment anyway. Common light-traps for windows are rigid boards or black hook-and-loop fasteners in combination with opaque cloth (see fig.5).

Verify the effectiveness of your light proofing efforts after giving your eyes a chance to adapt to the newly created darkness for at least 20-30 minutes. This is likely to reveal some remaining light leaks, and they need to be given further attention.

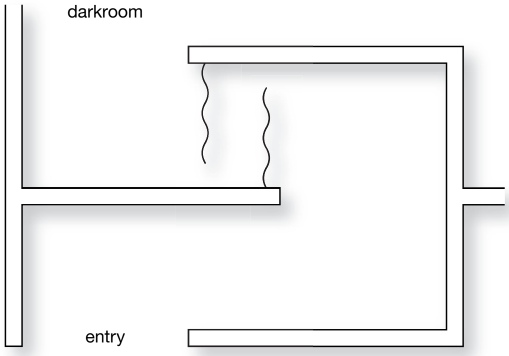


fig.3 Given sufficient floor space, a light-trapping entrance provides easy access without interrupting the ongoing darkroom session for others. The inside walls are painted flat black, and an optional set of light curtains provides extra protection if the darkroom entry is exposed to bright daylight.

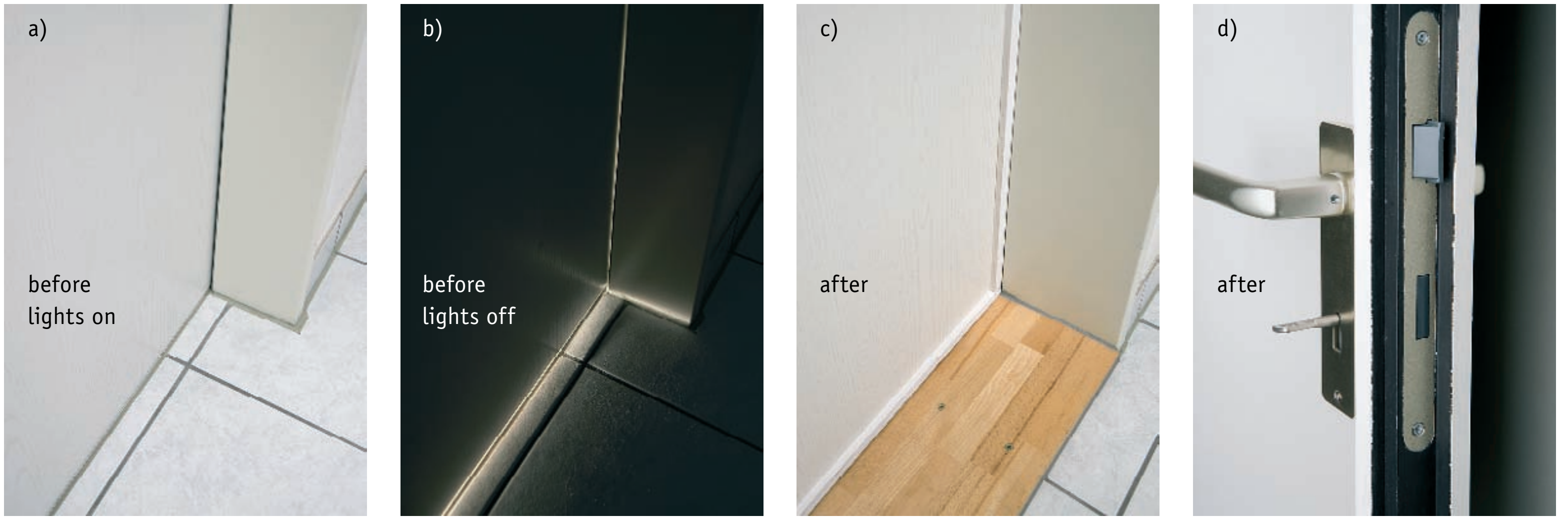
## Walls

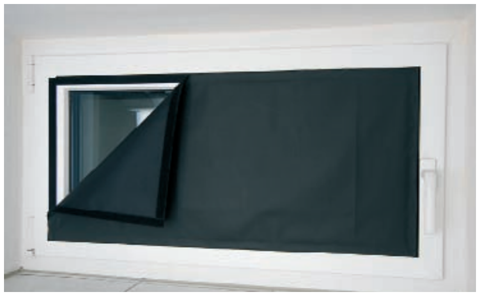
There was never any benefit to the old idea that all darkroom walls should be painted black. Modern darkrooms have ceiling and walls painted in white or any other light and friendly color, except for the area around the enlarger, which should be painted flat black. A light color helps to diffuse and evenly spread general darkroom illumination and safelighting. Black walls serve no practical purpose but create an unnecessarily depressive atmosphere.

## Ventilation

Inevitably, darkroom chemicals slowly release unpleasant and sometimes toxic odors. Large open trays are the worst offenders, due to their large liquid surface areas. This problem is more severe in a small space, but vertical slot processors are a big help, because they feature extremely small liquid surface areas, which minimizes unwanted odors and reduces chemical oxidation rates, while only occupying a remarkably small footprint. Nevertheless, some chemicals require the darkroom to be equipped with active ventilation, most commonly provided by a regular extractor fan in combination with an air inlet, but both fitted with a custom-made, light-trapping air-path (see fig.6). To keep things pleasant in a domestic environment, the fan must exhaust to the outdoors and not into an adjacent room. Even so, some chemical processes, such as sulfide toning, are either a threat to human health or at least sufficiently unpleasant as to leave outdoor processing as the only option.

fig.4 Regular door surrounds (a) have significant light leaks (b), which are easily eliminated by adding a light-trap in combination with a floor board (c) and painting all involved surfaces with a flat black paint (d).





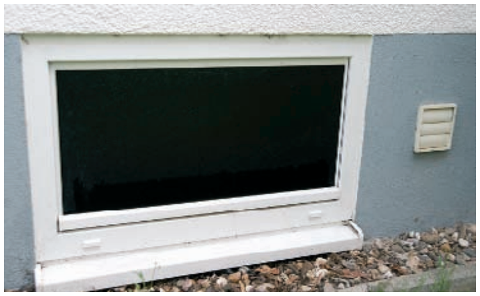


fig.5 Common light-proofing solutions for windows are rigid boards (right, here used outside) or black hook-and-loop fasteners in combination with opaque cloth (left, here used inside).

## Heating and Air-Conditioning

The choice of room has a significant influence on how easily a comfortable temperature can be maintained. For instance, basement darkrooms have a nearly constant temperature throughout the year and require the simplest of domestic appliances to maintain a stable temperature. Darkrooms in attics, garages or sheds, suffer from temperature extremes. For example, a large exposed roof area can heat or cool a room over a 35°C range, even with mild UK seasons. Insulation is an important consideration in such case, mitigating the issue to some extent, but without air-conditioning, these darkrooms may be out of bounds during the summer months, especially in warmer climates.

If a darkroom requires additional heating, it is best to avoid electrical fan heaters, because they circulate dust. Modern oil-filled immersion heaters are thermostatically controlled, safe, darkroom friendly and are available in a number of power levels. Some models have 24-hour timers, which allow setting a precise room temperature and warm up a darkroom prior to an early morning printing spree. However, darkroom processes themselves add heat and humidity to the room, which may require a dehumidifier or an air-conditioning unit. Since darkrooms invariably produce chemical fumes, a unit that exchanges air is preferred and helps with darkroom ventilation.

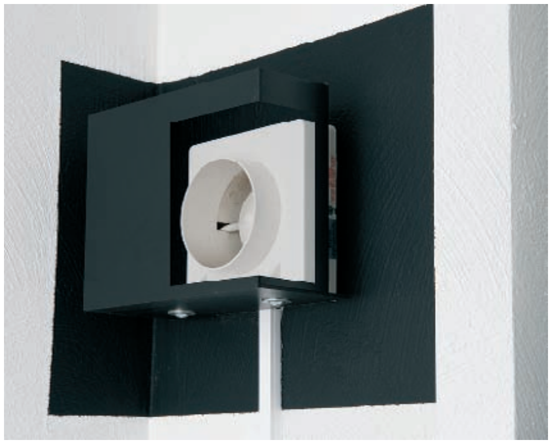


fig.6 Unwanted darkroom odors are effectively removed with a regular extractor fan and a custom-made, light-trapping air-path, which is illustrated here by a cut-away.

## Safelights

A single safelight, mounted in the center of the ceiling, provides effective illumination around the darkroom. Unfortunately, with such a light, no matter where you are in the room, you are inevitably working in your own shadow. Multiple low-powered safelights, strategically positioned above key work areas, solve this problem. As a rule of thumb, limit yourself to one 15W safelight for every 2 m$^2$ of darkroom floor space, and maintain a minimum distance of 1 meter between any safelight and open paper. Some enlarger timers reduce unnecessary safelight exposure by leaving safelights on for focusing but conveniently turning them off during metering and printing. Detailed safelight specifications are discussed in the next chapter.

## White Lights

In addition to the safelights, a darkroom also needs white lights for general room lighting and final print evaluation. For both purposes, incandescent lighting is preferred over fluorescent lighting. Incandescent bulbs are designed for frequent on/off switching. They have no lengthy ramp-up and are immediately at full power, which they maintain consistently. The bulbs do not continue to glow after they are turned off, and their color temperature is similar to typical domestic and gallery lighting, making incandescent lighting more conducive to accurate image tint evaluation.

A dedicated location for dry or wet print evaluation is an important feature of a well-designed darkroom. The area should be evenly illuminated and closely simulate final viewing conditions. Prints produced and evaluated in brightly lit darkrooms end up looking too dark in dimmer environments. A 60-100W opal tungsten bulb, a distance of 1-2 meters from the evaluation board, provides an illumination of around EV 6 at ISO 100/21° (see fig.8). This setup simulates rather dim display-lighting conditions and is ideal for dry print evaluation. However, don't forget to consider print dry-down when evaluating wet prints.

## Dry Side and Storage

The wet and dry areas of a well-designed darkroom should be separated for obvious reasons. Nevertheless, this becomes increasingly difficult as the room becomes smaller, and at some point, more imaginative solutions are required to organize the available space. A practical solution for darkroom furniture is using kitchen units with laminated worktops. This provides a clean work area and plenty of room for storage, which keeps enlarger, printing paper, negatives and other sensitive materials and equipment a safe distance from the wet side. Chemicals must be secured and kept out of reach of inquisitive children. Film and paper stock is best kept in a dedicated refrigerator.

A light-tight drawer keeps the printing paper accessible and protected during the entire darkroom session (fig.7). Use an existing drawer and cut a groove around its inside top perimeter. Install a sliding lid that fits in that groove and paint the inside of the drawer and the lid flat black. Now, attach a pair of small blocks of wood, one on the top of the lid and another one on the underside of the worktop. These blocks will close the lid when you close the drawer.

The effect of stray light, either directly from the enlarger or reflected from its surroundings, is effectively minimized by painting adjacent walls with matt black paint or hanging up black curtains. There should be sufficient headroom for the enlarger to reach its full height. Further enlargement can be achieved through lowering the baseboard or horizontal projection. During printing, a large uncluttered worktop is useful for laying out printing materials, negatives and burning or dodging tools. After print processing, this worktop can also be used as a matting and mounting area.

## Wet Side and Plumbing

It is possible to design a darkroom completely without running water, which forces you to bring in buckets of water as the main water supply, create holding tanks, and carry chemically processed prints to another room for washing. This may suffice for a temporary darkroom setup, but it quickly becomes cumbersome. To work efficiently, a darkroom must have running hot and cold water, as well as waste-water drainage.

Another darkroom convenience is one or two large darkroom sinks. A small sink, with a work surface right next to it, works well for vertical slot processors and careful practitioners, but large sinks are ideal for tray processing. Having two sinks next to each other effectively separates chemical processing from print washing and provides an additional wet area to clean up recently used equipment. Professional plastic and steel sinks are manufactured in various sizes, but they can also be custom-made from wood with fiberglass lining. Substantial darkroom sinks employ a modular steel, or wooden, framework to support the sinks and provide shelf space underneath. A very useful feature is raised ridges in the sink, which are level for the trays to sit on but still allow the sink bottom to slope gently back to the drain (see fig.11).

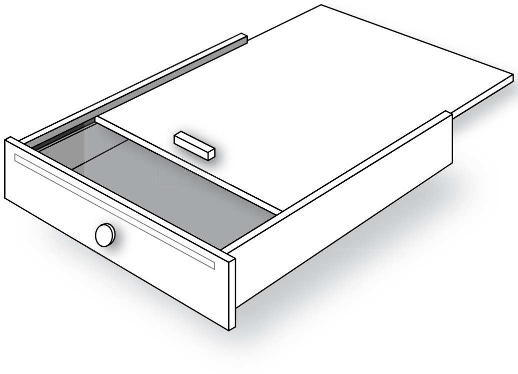


fig.7 A light-tight drawer keeps the printing paper accessible and protected during the entire darkroom session.

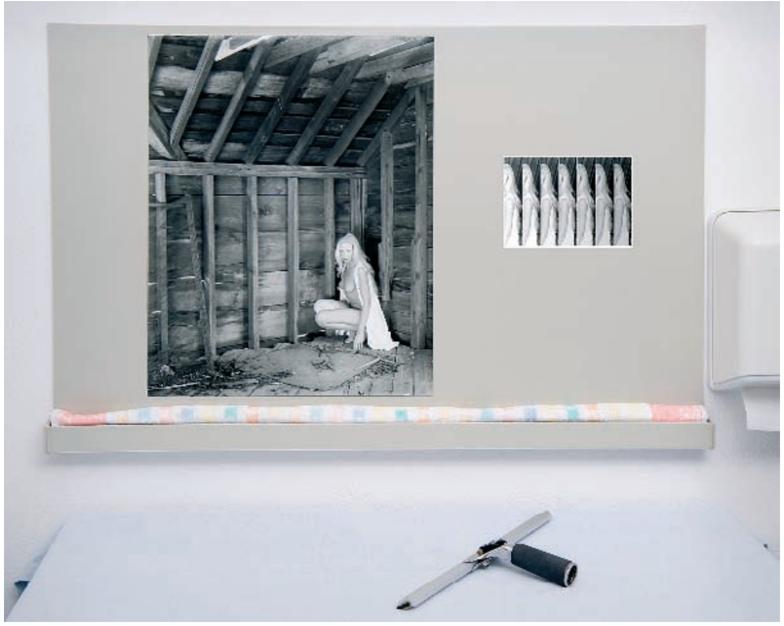


fig.8 A dedicated location for print evaluation is an important darkroom feature. It should be evenly illuminated and closely simulate final viewing conditions.

Further refinements may include an automatic mixing valve that electronically controls water flow and temperature, which is an investment neither of us ever regretted. Also, the availability of multiple faucets provides the opportunity to install dedicated plumbing for an archival print washer, while still having running water for other purposes. Alternatively, one may attach a range of devices to the same faucet with snap-fits, such as those used for garden hoses.

Water quality varies between regions and should not be taken for granted. Some supplies carry sediment, which may potentially damage wet negatives or become permanently embedded in the film or print emulsion. Sediment can be avoided by installing an in-line water filter, and by using distilled water for the film chemistry and the final rinse. This also reduces the possibility of creating drying marks with hard water deposits. Please note that highly dilute developer solutions are susceptible to alkali or acid water supplies, and that it is best to bypass the water softener for more effective film and print washing. Environmentally responsible darkroom workers collect used darkroom chemicals and hand them over to their local waste management centers rather than pouring them down their drains.

## Cleanliness

Fastidious cleanliness is not optional when trying to produce fine-art prints. To avoid contamination during processing, use only dedicated equipment for each processing step, and never move utensils backwards in the processing chain. For example, once a plastic bottle has been used for developer, always use it for developer. And, if a print tong has been accidently moved from the developer to the stop bath, do not move it back until it has been thoroughly cleaned. That's why they are color-coded! At the end of your darkroom session, clean and dry all trays and utensils immediately. Liquid darkroom chemicals are easily washed off. Dried fixer, for example, is a different story.

Keeping dust under control minimizes the need for print spotting. Reduce dust levels by keeping the darkroom door closed. Surfaces made of ceramic tiles, sealed concrete or hardwood flooring and rubber mats work well, since they are not only dust free, but they are also easy to clean, and accidental spills can be mopped up quickly. Carpets, on the other hand, collect dust, are hard to keep clean and build up static charges. Storing the enlarger and easel under a dust cover and wearing only lint-free clothing are precautions that reduce the need for spotting the prints later on.

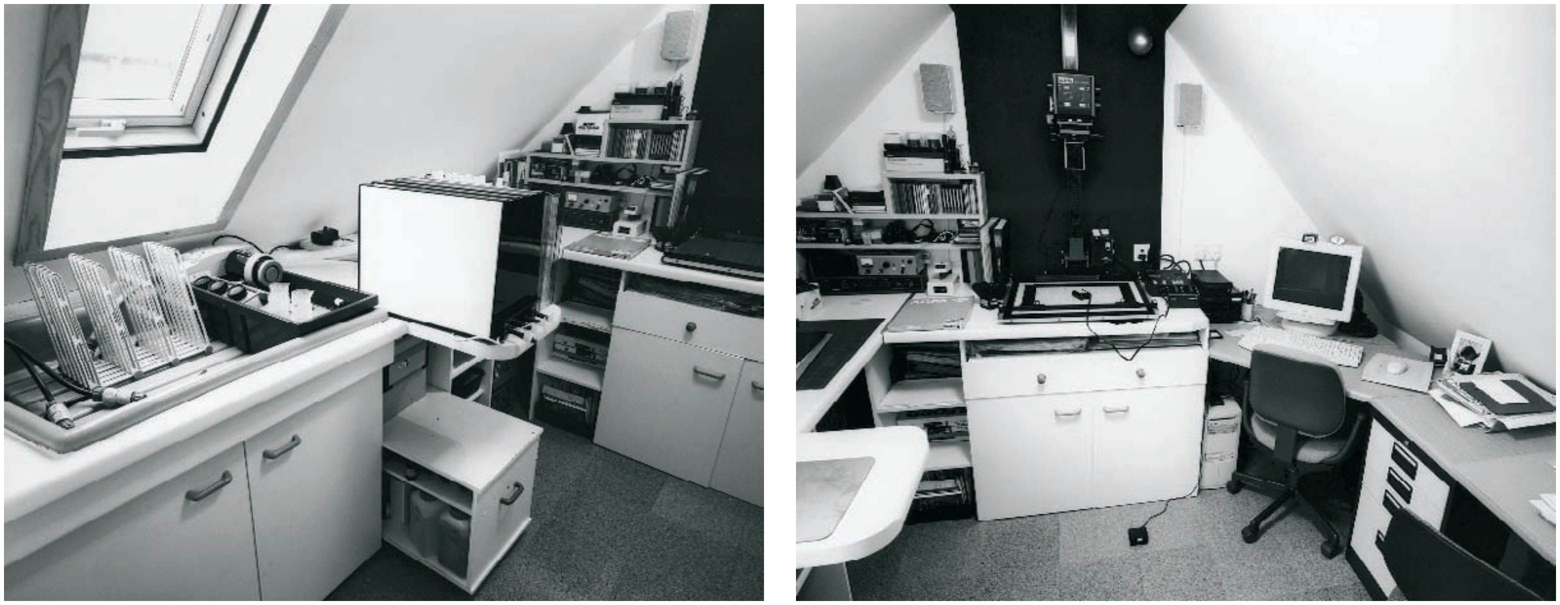


fig.9 This remarkable attic extension contains a darkroom and an office. The enlarger is set at the apex with the wet side to the left and the office to the right. The film processor is inside a large plastic sink, and beside it, a vertical slot processor juts out into the room to allow enough headroom to pull out a print. Underneath, a pullout unit stores film and paper processing chemicals.

## Darkroom Safety

Besides being a comfortable recreational place, darkrooms must also be safe environments. Always keep in mind that electricity and liquids do not mix. At some point, wet hands will operate electrical devices. For this reason, all electrical outlets must have earth-leakage protection. Fuse ratings must match the equipment requirement, and all electrical outlets must be positioned away from likely splash sources and certainly not upward facing. Unoccupied outlets are safer if fitted with childproof covers. Allow no electrical wiring on the floor to prevent the danger of tripping over it in the dark.

Darkrooms are not inherently dangerous places, but the limited illumination level, the use of potentially hazardous chemicals, and the close proximity of electricity and water must be seriously considered. Eating, drinking and smoking are not compatible with safe darkroom practice. Also, consider indicating the position of switches, electrical outlets and door handles with luminous paint or stickers. Designing and building your own darkroom is a satisfying experience, but if ever you are in any doubt, play it safe and hire a certified craftsman for all electrical, plumbing and heating installations, and make sure all local building codes have been followed.

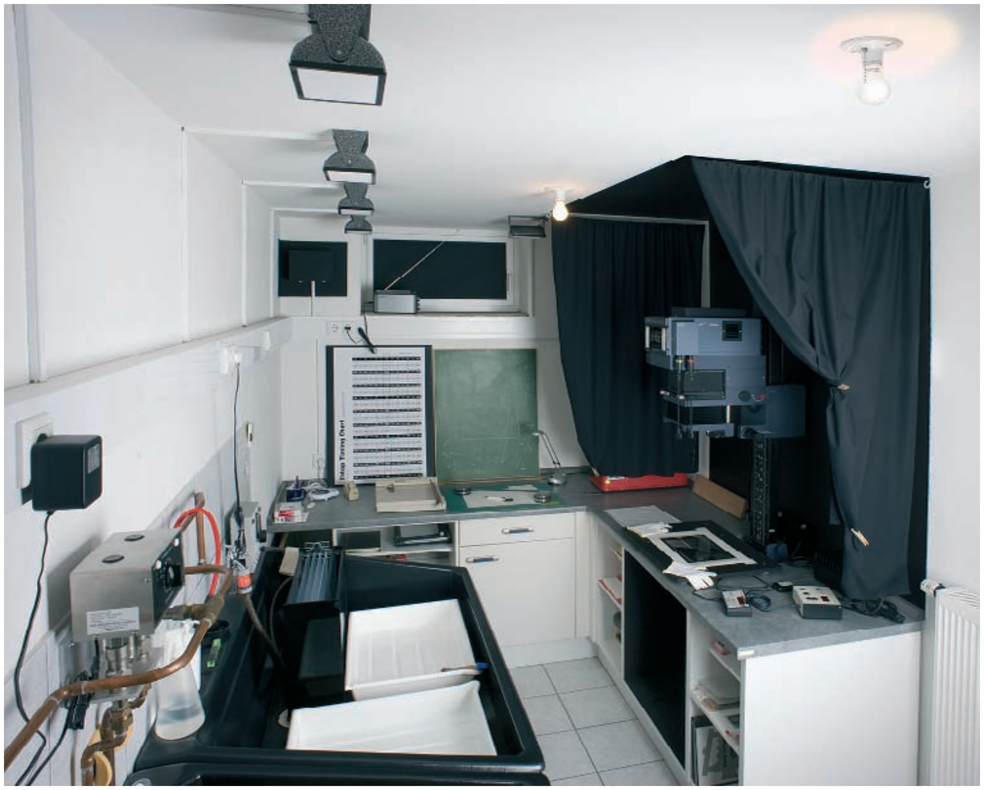


fig.10 (top) This medium-size darkroom in Ralph's basement offers a clear separation of wet and dry processes and ample space for tray processing. Multiple safelights are distributed throughout the room, and stray light from the enlarger is minimized by black curtains.

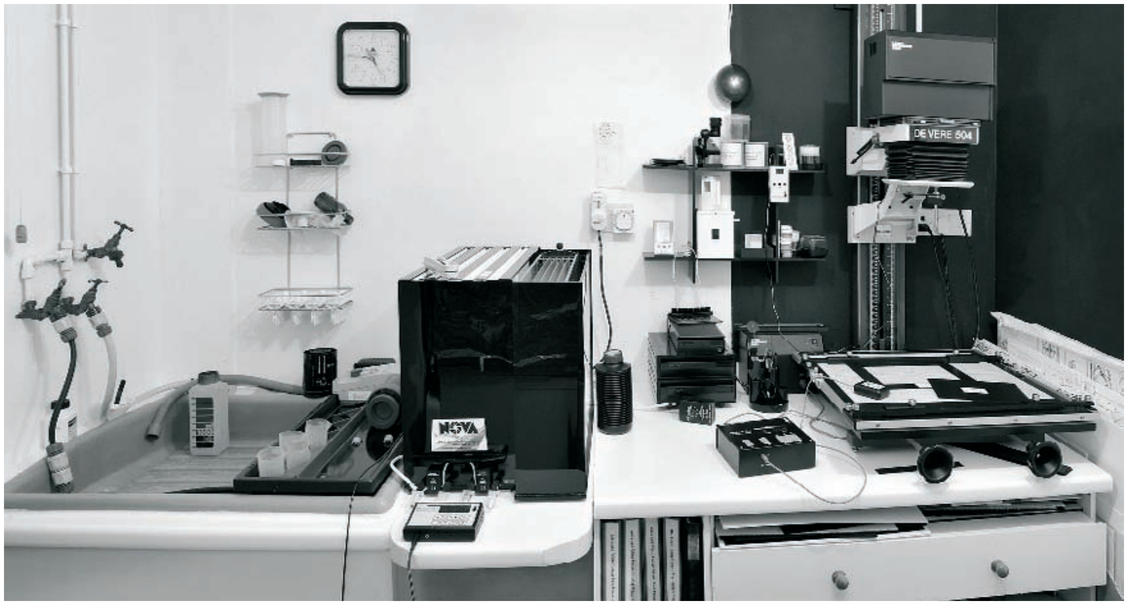


fig.11 (left) Chris's garage darkroom has everything he needs to create prints up to 16x20 inches. It is home to a 4x5 enlarger, a print washer and a vertical slot processor. The garage is effectively insulated with polystyrene blocks to keep the temperature at a pleasant 20°C.

# How Safe Is Your Safelight?

## Two simple, reliable tests with surprising results

We want our photographic paper to be sensitive to light, but we do not like to be in complete darkness when we work with it. The photo industry has a solution for this contradiction.

Photographic paper is only sensitive to a certain range of the visible spectrum. In addition, safelight filters transmit only light from a different range of the visible spectrum. This way, our eyes and the paper are sensitive to the light projected by the enlarger, but only our eyes and not the paper are sensitive to the light illuminating the darkroom.

Fig.1 shows how sensitive variable-contrast (VC) papers are to blue and green light, which require a safelight output limited to wavelengths above 560 nm, in order to protect the paper from unwanted exposure. Kodak's 'light red' (1A) and 'light amber' (OC), or Ilford's 902 and 904 safelight filters fulfill this requirement. Filter 1A provides more protection, because it only transmits wavelengths above 600 nm, but the eye is not particularly sensitive to this light, and consequently, this filter makes for a rather dim darkroom environment. The OC filter, on the other hand, transmits light in wavelengths very close to the human peak sensitivity, providing a much brighter workplace and softer illumination. Both filters are sold as being 'safe', because they do not emit any light to which typical papers have any significant sensitivity.

Unfortunately, this is not entirely true for several reasons. First, the papers are not totally insensitive, but have a very low sensitivity outside the intended spectrum. Second, the safelight filters transmit minute levels of light outside their intended spectrum, and this effect increases with their age. Third, the safelight housing, depending on design and quality, may have some minor, unintended light leaks.

This requires that we rephrase the statement about safelights. Safelights protect photographic paper only for a

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50070-3

limited amount of time, after which non-image forming exposure becomes visible. Consequently, we need to know how long the paper is protected, and how to test the safelight condition reliably.

## Paper Characteristics

You can see in fig.2 how photographic paper responds to the light it was designed for. The paper characteristic curve represents density levels achieved by any given amount of exposure.

Initially, illustrated through the shallow ramp up at the toe of the curve, a small amount of exposure is required just to get the paper 'started'. Minute amounts of light leave the paper unaffected until a moderate amount achieves the 'first usable density'. The human eye is most discriminating to the small differences in density in these highlight areas.

The paper, on the other hand, is most sensitive in the midsection of the curve, where even small exposure changes result in significantly different densities. In the shoulder of the curve, a certain density saturation has taken place, and additional exposure add relatively small density increases until a maximum black has been reached. The human eye is not particularly sensitive in these shadow areas, and is unable to see density differences after a certain point, which is referred to as the 'last usable density'.

## Image Exposure

The paper characteristic curve in fig.2 also illustrates that small amounts of exposure, similar to typical safelight illuminations, do not harm unexposed paper, because this limited exposure cannot overcome the initial inertia of sensitivity. A certain amount of light is first required to get beyond the horizontal portion of the toe. In a typical darkroom session, this hurdle is taken when an exposure is made to get the brightest tonal values of the image to the point of the 'first usable density'. This exposure sensitizes the paper to any further illumination. From this point on, even small amounts of exposure will increase density in all tonal values, but most visibly in the highlights. Safelight illumination, both before and after this image forming exposure, can only be tolerated for a certain length of time, after which a density increase visible to the human eye results. We will try to duplicate these conditions to design a practical and representative safelight test.

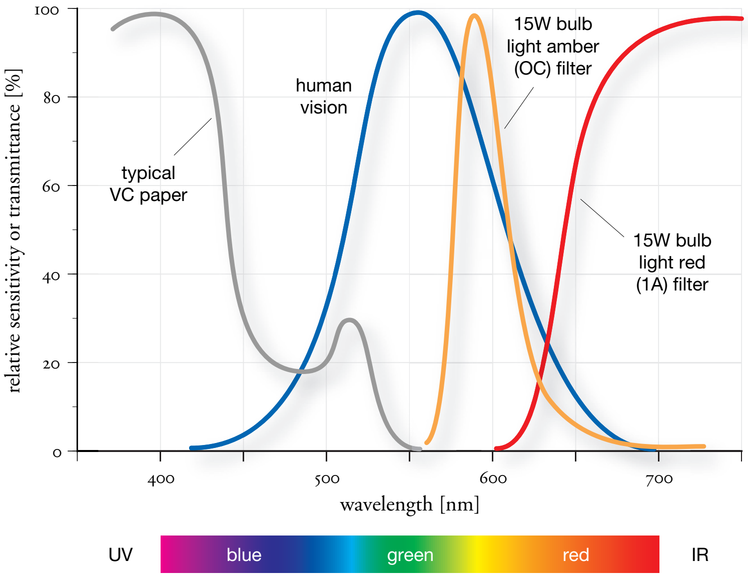


fig.1 Incandescent illumination in combination with light amber (OC) or light red (1A) filtration protects the paper against fogging for several minutes, because it does not emit any significant radiation to which the paper is sensitive. However, amber filters provide more visible radiation than red filters, creating a much brighter environment in the darkroom.

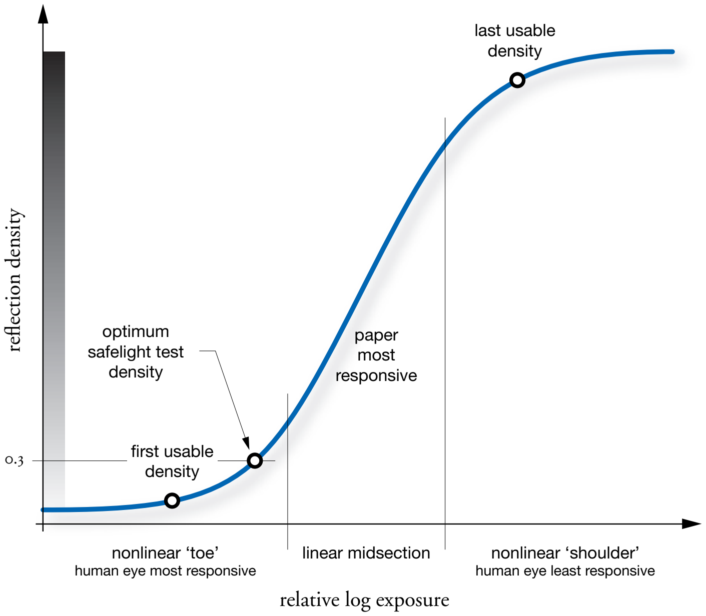


fig.2 The paper characteristic curve shows how paper densities increase with exposure. Initially, however, minute amounts of light leave the paper unaffected.

Safelights protect photographic paper only for a limited amount of time, after which non-image forming exposure becomes visible.

Typical variable-contrast papers are appropriately protected with a light-amber (OC) safelight filter, but some papers need the stronger protection of a light-red (1A) filter. Fast orthochromatically sensitized papers need the strongest protection and require a dark-red (2) filter.

**Simulating Image Exposure**

The image exposure through the negative is best simulated with the 'optimum safelight test density'. This is a good compromise between the 'first usable density' (Zone VIII), where the eye is most sensitive to density changes, and the 'linear midsection' (Zone V), where the paper is most responsive to exposure increases.

In total darkness and without film in the negative carrier, produce a test strip on 'normal' graded paper, to find the enlarger exposure required to produce the 'optimum safelight test density'. This is a light gray tonal value between Zone VI and Zone VII, or about 0.3 reflection density. A high degree of accuracy is not required at this point. Use a step tablet, a zone ruler, or print it just a little darker than you typically print your textured highlights.

## A Precise Test

You will need a single sheet of 8x10-inch paper and two thick pieces of cardboard. One piece, the mask, requires a 4x8-inch cutout, and the other piece is needed to cover the test strips. Trim one corner of the mask, because this will aid in the orientation of the paper. Make sure that all processing chemicals are prepared. A 'normal' filter is placed into the light path and the lens is set to an aperture that, in combination with the proper exposure time, will produce the 'optimum safelight test density'. Place an empty tray on top of the development tray, which will be required later as a physical support for the paper.

The following steps can be executed in any order, since the exposures are accumulative. Customize all times to simulate your own work habits.

**1. On the Baseboard**

In the dark, center the paper on the baseboard and cover it with the mask. Turn the safelight on. Immediately cover the first horizontal step, about 1 inch, and continue to cover more steps resulting in a practical pre-exposure sequence that reflects your own work habits. I usually simulate pre-exposure paper handling from 0-16 minutes in intervals as shown in the examples. As an optional step, you could turn the enlarger 'on' for the first 2 or 3 minutes of the pre-exposure, while shading the paper with one of your dodging or burning tools. This tests for any light leaks from the enlarger and/or reflections from the surrounding walls. Turn the safelight off.

fig.3 (right) This safelight allows for 6-minute paper handling on the baseboard but only 2 minutes in the development tray, a performance hardly worthy of being referred to as 'safe'.

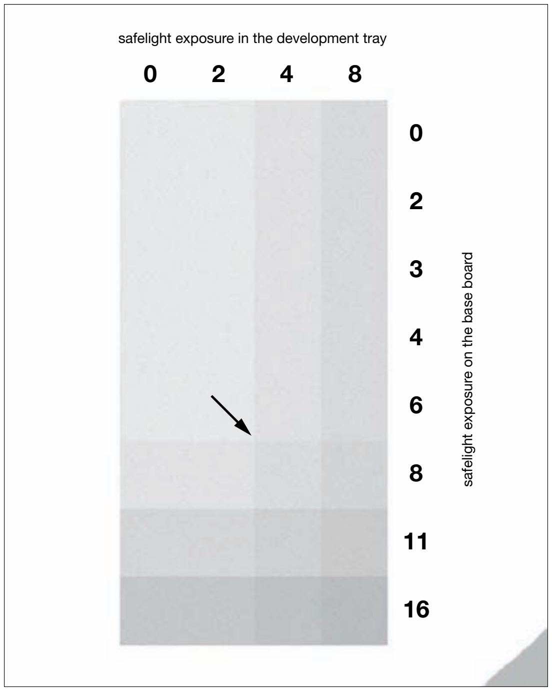
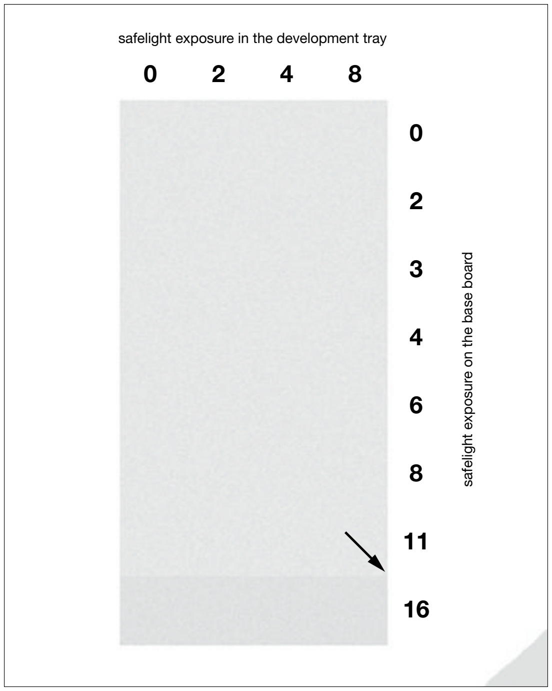

safelight exposure in the development tray
0
2
4
8
0
2
3
4
6
8
11
16
safelight exposure on the base board

fig.4 (far right) This safelight allows for 11-minute paper handling on the baseboard and 8 minutes or more in the development tray. This is fully adequate for most printing sessions.


safelight exposure in the development tray
0
2
4
8
0
2
3
4
6
8
11
16
safelight exposure on the base board

### 2. Exposing the Print

While still in the dark, turn the enlarger on to expose the paper for the 'optimum safelight test density'. This simulates the image exposure and was pretested earlier. Leave the safelight off.

### 3. In the Developing Tray

Again in the dark, place the paper with the mask on top of the development tray. Turn the safelight on. Immediately cover the first vertical step, about 1 inch, and continue to cover step by step creating a practical post exposure sequence, reflecting your own work habits. I usually simulate post exposure paper handling, including the development process, from 0-8 minutes in intervals as shown in the examples. Some printers ignore this step, because they believe that paper loses its sensitivity to light as soon as it becomes wet. I have found no evidence for this claim. Finish the test by processing the paper normally in the dark.

## Test Evaluation

Three possible results are shown in the test print examples. Keep in mind that the top left patch, which we will refer to by its coordinates 0-0, has not been exposed to any safelight, but was sensitized, simulating print exposure, in step 2.

The first example, see fig.3, was exposed to two different safelights, one close to the enlarger and the other above the development tray. The test shows a very poor safelight performance. The last patch matching the gray value of the top left corner is patch 2-6. This means this paper should not be exposed to the safelight conditions around the baseboard for any longer than 6 minutes. The safelight conditions at the development tray allow for an additional exposure of no more than 2 minutes. The baseboard time could be adequate, if no special paper handling were required, but the time in the development tray is too short for even the processing of resin-coated papers. The owner of this darkroom should check all safelights, but the light near the development tray needs to be replaced or checked for light leaks.

The second example, see fig.4, was exposed to the same safelights after bulbs and filters were replaced, and a small light leak in one of the housings was taped over. The test shows a very good safelight performance. The last patch matching the gray value of the top left corner is patch 8-11. This means that the paper can be exposed to the safelight conditions around the baseboard for about 11 minutes. The safelight conditions around the development tray allow for an additional exposure of at least 8 minutes. The baseboard time is long enough for most paper handling, and the time in the development tray is adequate for the processing of fiber-base papers. The owner of this darkroom can trust the safelights unless special processes, like lith printing, requiring long times in the development tray are used. In that case, the test times have to be modified to reflect the special requirements.

The third example, fig.5, was exposed with the same safelights as in the previous example, with one addition. The enlarger was 'on' during the first 3 minutes of the pre-exposure, while the paper was shaded with a burning card. The test shows a very good safelight performance, but enlarger light leaks and reflections have reduced this to less than 2 minutes.

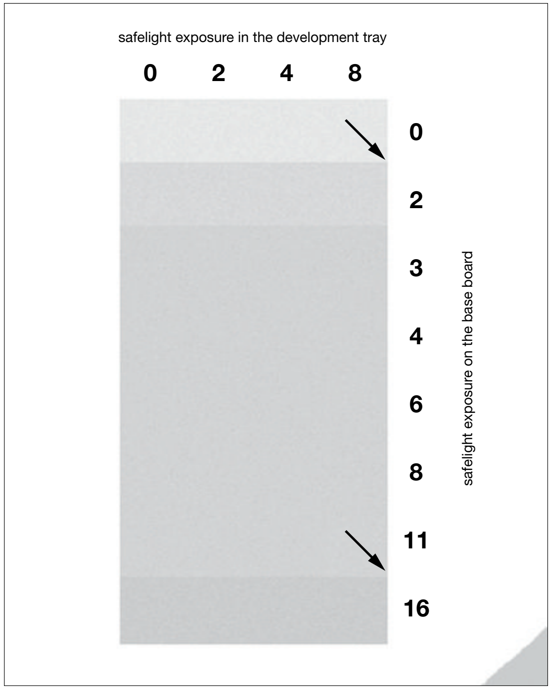

safelight exposure in the development tray
0
2
4
8
0
2
3
4
6
8
11
16
safelight exposure on the base board

fig.5 Here the enlarger was 'on' during the first 3 minutes of the pre-exposure, while the paper was shaded with a burning card. The safelights protect as in fig.4, but enlarger light leaks and reflections fog the paper in less than 2 minutes.

The last patch matching the gray value of the top left corner is patch 8-0 and no further change can be seen until patch 8-11. This means that the paper can only be exposed to the safelight conditions around the baseboard for less than 2 minutes. The safelight conditions around the development tray allow for an additional exposure of at least 8 minutes. The time in the development tray is adequate, but the baseboard time is too short for real world paper handling. The owner of this darkroom must make several changes to the darkroom. Suggestions would include the following steps. The walls around the enlarger should be painted flat black. The enlarger itself should be checked for light leaks and reflections. Confirm that cards, used for dodging and burning, do not transmit any light to the print. The printer should also wear dark clothing to reduce reflections.

This valuable test can be performed in about 30 minutes, and I repeat it every 3 to 6 months, just to be sure. It is a great assurance to know that the safelights are not affecting print highlights and image quality during normal processing times.

## The Coin Test

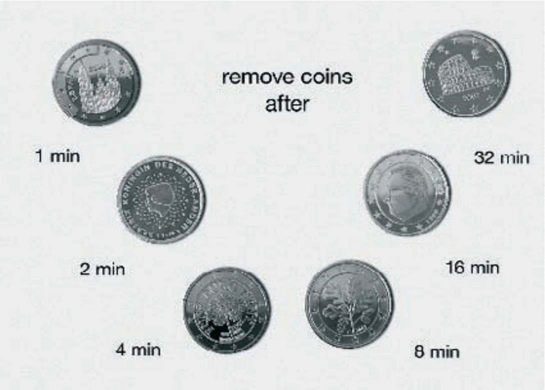
The previous test clearly identifies any source of light contamination and quickly points to the area that requires improvement. The coin test is not quite that sophisticated and does not discriminate between different sources of light contamination, but properly executed, it is a reliable check and is easily done.

1. In the dark, pre-expose a sheet of paper, so it will produce a light-gray density, once it is processed.
2. Still in the dark, put the paper on the work surface, right under your safelight, and randomly distribute six coins on the paper, as seen in fig.6.
3. Now, turn the safelight(s) on, and after 1 minute, remove the first coin.
4. Remove the other coins after a total of 2, 4, 8 and 16 minutes, but do not remove the last coin.
5. After 32 minutes, turn off all safelights, remove the last coin, and process the paper normally.

Depending on how ‘safe’ your safelight illumination is, the coins will have left more or less ghostly evidence about their previous positions on the paper. After this quick test, you will have a pretty good idea of how long you can work under the safelights, without adding unwanted fog to your print’s highlights.

The test example in fig.6a illustrates the effect of a poor safelight protection. With the exception of the 1-minute coin, all coins have left their telltale signs. This indicates that the safelight illumination is, unfortunately, strong enough to affect the print’s highlights in less than two minutes.

The test example in fig.6b, on the other hand, indicates a fully adequate safelight protection. The only still-visible remnant is the shape of the coin that covered the paper for 32 minutes. This safelight can be trusted to protect delicate print highlights for at least 16 minutes and maybe longer.



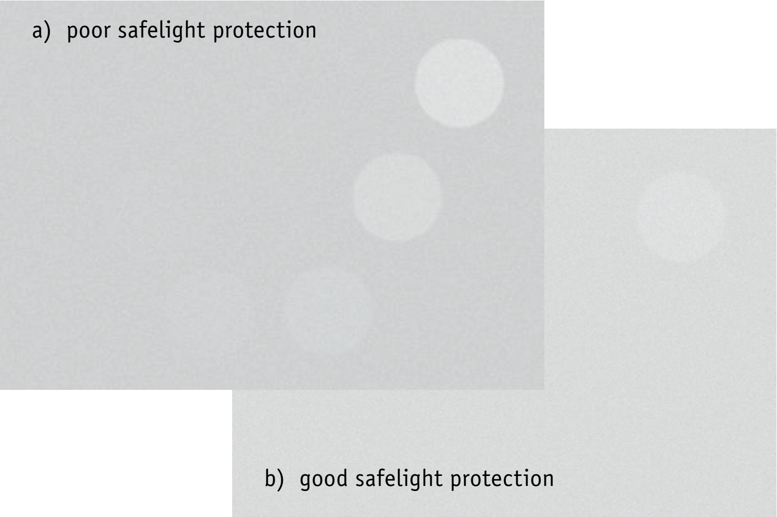


fig.6 The coin test is not as sophisticated as a precise safelight test, but it is a reliable check and is easily executed.

# Enlarger Light Sources

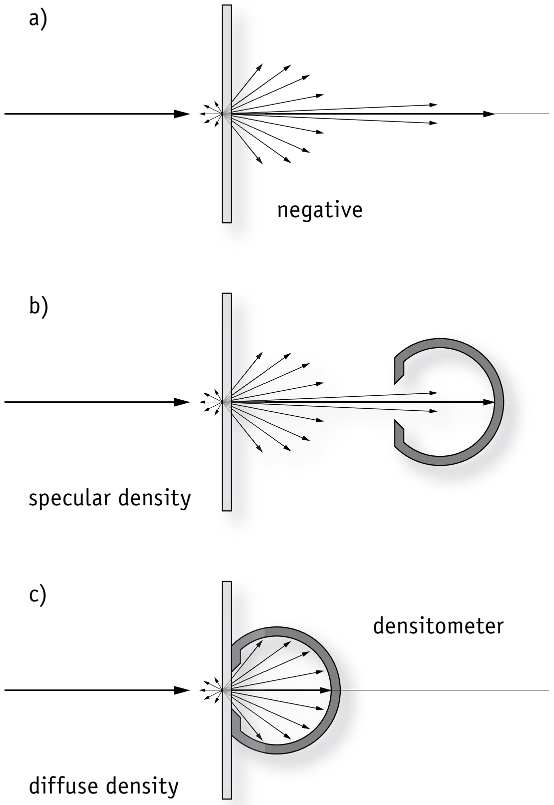
## The difference between condenser and diffusion enlargers

The enlarger is the fundamental instrument of every darkroom worker, and considerable thought should be given to its selection. After considering the most obvious enlarger specifications, including supportable negative formats and the sturdiness of design, an informed choice of light source must be made. Unfortunately, the enormous amount of conflicting information available on this topic does not make this an easy task.

© 2008 by Marco Morini, all rights reserved

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50071-5

fig.1 When light falls onto a negative, some of it is reflected and absorbed, while the remainder is scattered and passed through the negative (a). Depending on how density is measured, different numerical values are obtained. Specular density is given when only the near perpendicular component of the transmitted light is measured (b). Diffuse density is obtained if the entire transmitted light is considered (c).



The majority of enlarger light sources can be separated into two categories: condenser and diffusion. Selecting one light source over the other is often influenced by the advice of more experienced darkroom workers' biases and subjective advertisement claims. This chapter attempts to objectively compare both enlarger light sources.

## Density Measurements

When light falls onto a negative, some of it is reflected, some is absorbed, and the remainder is scattered and passed through the negative (fig.1a). The exact pattern of light scatter depends on the light source and the material properties of negative emulsion and substrate. Different numerical values for negative density are obtained, depending on how the transmitted light is measured. Specular density is given when only the near perpendicular component of the transmitted light is measured (fig.1b). Diffuse density is obtained if the entire transmitted light is considered (fig.1c).

In practice, enlarging a negative and measuring its projected transmission density (fig.1b) returns a specular density reading, and measuring the negative transmission density with a densitometer in contact (fig.1c) returns a diffuse density reading. One way to compare the effect of specular versus diffuse density is to note the reflection density differences between an enlarged and a contact-printed step tablet.

## Callier Effect

At the beginning of the 20th century, André Callier (1877-1938), a young Belgian physicist, was the first to thoroughly investigate light scattering in silver-based photographic negatives and to analyze the relationship between specular and diffuse density. He demonstrated that the silver particles, which make up the image, are the main reason for the light scatter, and that the light loss to this scatter is responsible for the fact that specular density values are always higher than their diffuse counterparts.

### Callier Coefficient

The Callier coefficient or Q-factor is the ratio of specular density ($D_s$) to diffuse density ($D_d$).

$$Q = \frac{D_s}{D_d}$$

Callier believed that Q is a constant at all values of diffuse negative transmission density for a given film/developer combination, and that it is possible to

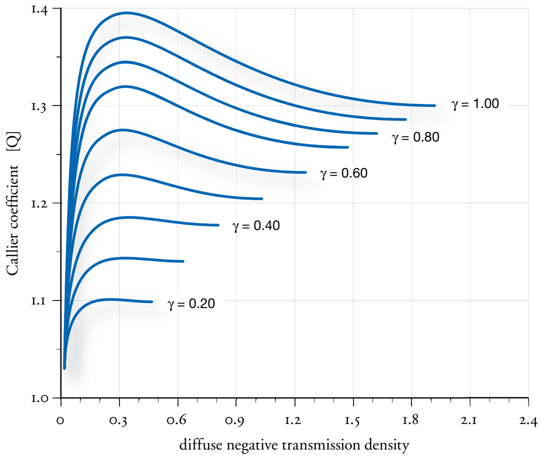


fig.2 The Callier coefficient or Q-factor is the ratio of specular to diffuse negative density. It varies with negative gamma and initially differs with the amount of diffuse negative density before reaching a constant value.

apply a simple density correction to any densitometer reading and compensate for specularity.

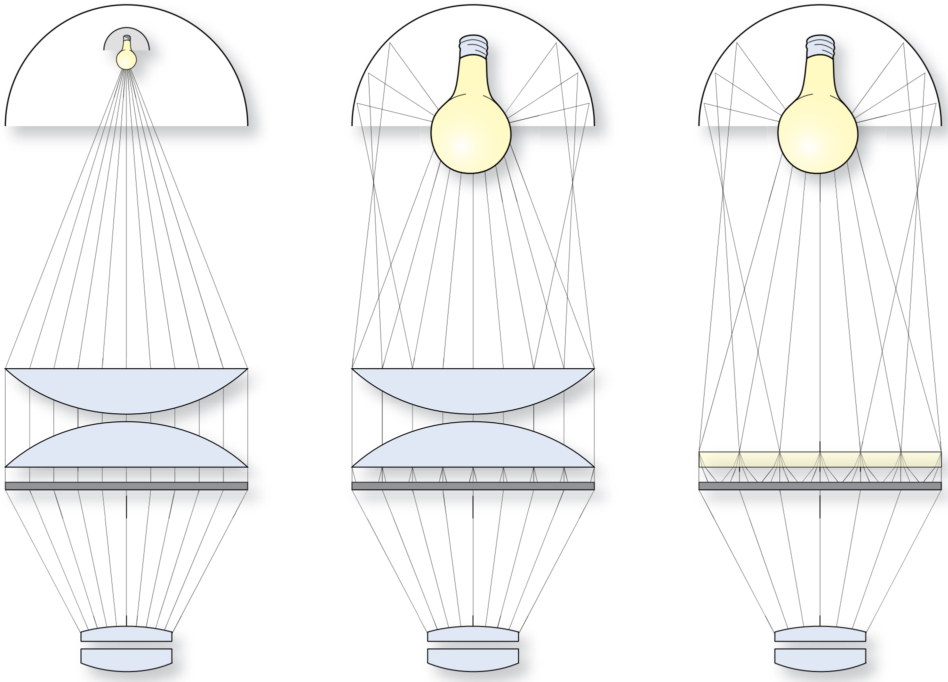
It was eventually discovered by other researchers that the Callier coefficient does indeed increase with negative grain size, but that Q is not a constant. Even if the same film/developer combination is used, Q varies with negative gamma and initially differs with the amount of diffuse negative density, before reaching a constant value. Fig.2 shows typical values for Q when projecting fine-grain negative film with a common condenser enlarger. Obviously, a simple density correction for specularity cannot be made.

It is important to repeat that the Callier effect results from the scattering of light by the silver grains in a conventional silver-gelatin negative. It does not occur with the non-scattering dye images of chromogenic films or ordinary color negatives.

## Condenser versus Diffusion Enlarger

The difference between condenser and diffuser enlargers lies in the way they distribute the light over the negative to provide uniform illumination. In condenser enlargers, a set of two plano-convex lenses, with the convex sides facing each other, is used to collimate the light and project it perpendicularly onto the negative (fig.3a&b), whereas in the simplest of diffusion enlargers, the light illuminates a translucent diffusion screen close to the negative (fig.3c). This fundamental design difference between condenser and diffusion enlargers has a significant impact on the overall contrast of the projected image. Callier's investigations revealed that collimated light sources lose significantly more light to scatter than diffused light sources. Since collimated light sources project the light perpendicularly onto the negative, most of the light scattered by the image particles is reflected away from the lens. A highly diffused light source, on the other hand, generates illumination coming from all angles, and as a result, much of the scattered light is reflected towards the lens. This explains why condenser enlargers have considerably higher Callier coefficients than diffusion enlargers. Furthermore, assuming a fairly constant Q-factor across all diffuse negative densities, negative highlights lose more light than negative shadows in absolute value, because they are richer in silver deposits and scatter more light. This is why a condenser enlarger produces a higher-contrast print from the same silver-gelatin negative than a diffusion enlarger.

In practice, the contrast difference between condenser and diffusion enlargers amounts to about one paper grade. In other words, to produce an equivalent



a) point light source

b) condenser enlarger

c) diffusion enlarger

fig.3 Actual negative illumination differs with enlarger design. Enlargers using a point light source and a set of double condensers to collimate the light (a) produce nearly totally collimated illumination. A condenser enlarger (b) with its relatively large light source supplies a semi-diffused light. By replacing the condensers with a diffusion screen, a diffusion enlarger (c) ensures nearly totally diffused negative illumination.

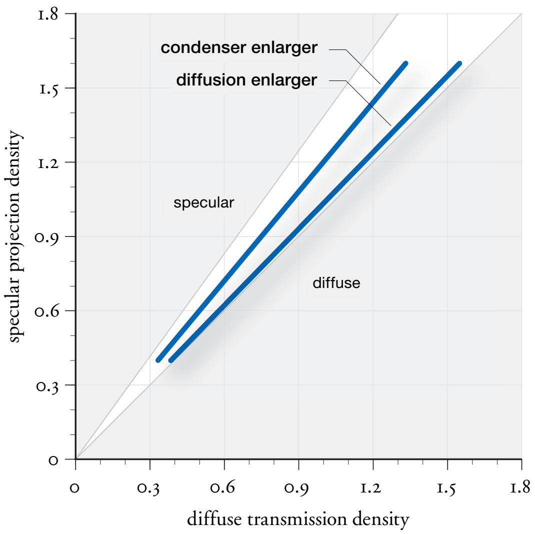


fig.4 A condenser enlarger creates higher projection densities and more contrast than a diffused light source.

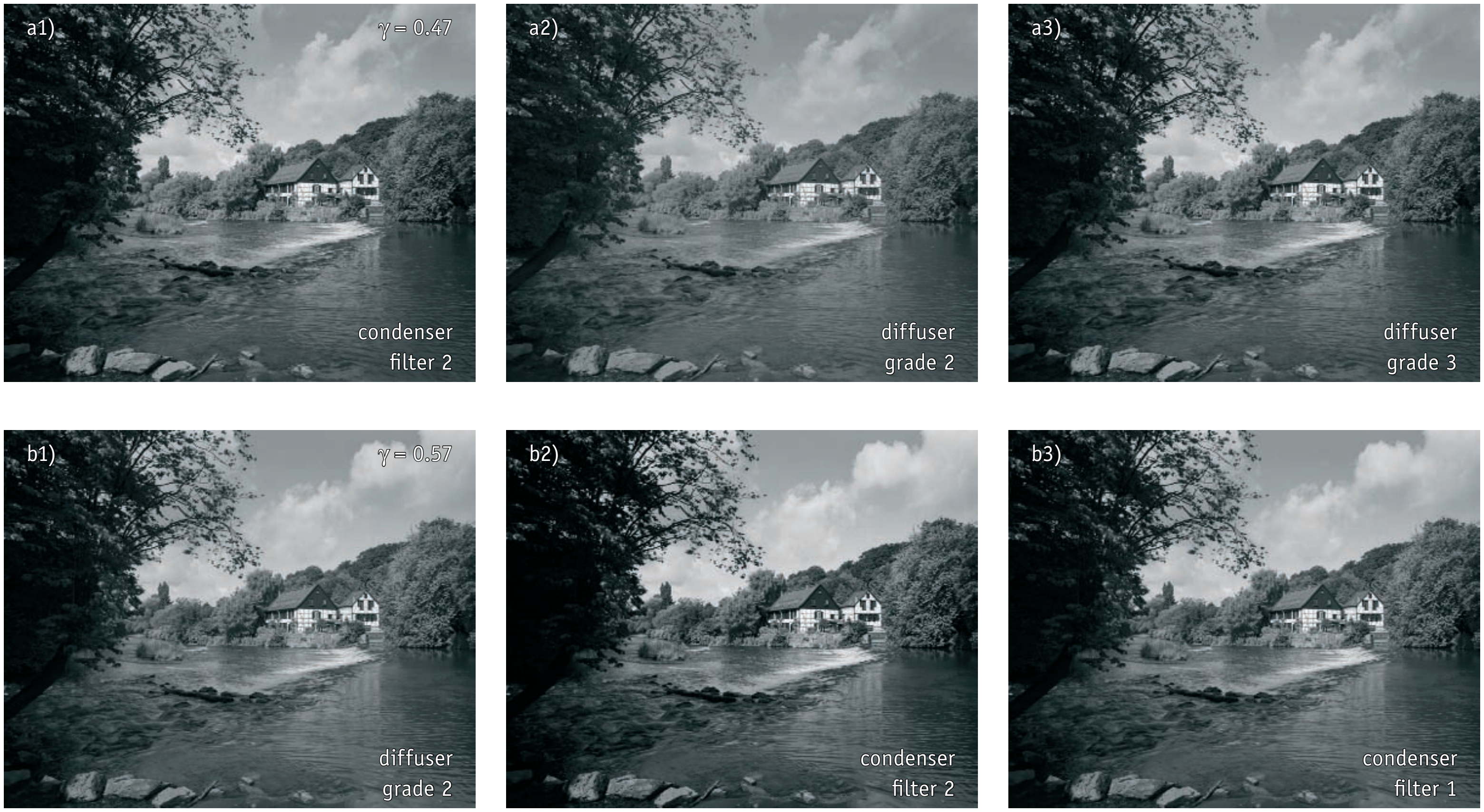


fig.5 Condenser and diffusion enlargers produce prints of identical tonality with negatives, which were developed to an average gradient, appropriate for each enlarger (a1 and b1). A negative that prints well with a condenser at grade 2 prints too soft with a diffuser at the same grade (a2), and a negative that produces a perfect print with a diffuser prints too hard with a condenser (b2). However, adjusting the paper contrast compensates for a less than perfect negative contrast and produces almost indistinguishable prints with either enlarger (a3 and b3).
(all images optimized for highlight density)

print, the average silver-gelatin negative requires a paper that is about one contrast grade softer when using a condenser enlarger than when using a diffusion enlarger. However, this contrast difference is only an issue when trying to produce equivalent prints from the same negative, using different enlargers. Photographers who predominantly use just one type of enlarger should develop their negatives to support their enlarger's contrast behavior. In simple terms, a high-contrast enlarger needs a low-contrast negative, and a low-contrast enlarger needs a high-contrast negative. The optimal negative-contrast value depends on the enlarger's Callier coefficient for a particular film/developer combination.

All condenser enlargers, except those with a true point light source, are partially diffusing. Point-light-source enlargers (fig.3a) are usually limited to scientific applications, but they serve as an example of totally specular illumination. A more typical arrangement for condenser enlargers is to use a large opal bulb inside of a reflector housing (fig.3b). This design adds diffused light and places a typical condenser enlarger about halfway between specular and diffuse illumination with an average Q-factor of approximately 1.2 (fig.4). By reducing the film development time, and thereby lowering the negative's contrast, any contrast increase due to the Callier coefficient can be fully compensated. The target value for the average gradient of a specific condenser enlarger ($\gamma_s$) is given by:

$$\gamma_s = \frac{\gamma_d}{Q}$$

where '$\gamma_d$' is the optimized average gradient for totally diffused illumination (typically 0.57), and 'Q' is the enlarger's Callier coefficient for a particular film/developer combination. Customizing negative contrast in this way ensures equivalent prints with condenser and diffusion enlargers on the same grade of paper.

### Pictorial Comparison

To compare the tonal differences between condenser and diffusion enlargers, a low and high-contrast negative were prepared, and both were printed with a Durst L1200 condenser and diffusion head. The negatives were developed to an average gradient of 0.47 and 0.57, optimized for typical condenser and diffusion enlargers, respectively. In each case, the print exposure was adjusted to keep a constant highlight density in the white walls of the exposed-beam buildings (fig.5).

Condenser and diffusion heads produced almost identical prints from the negatives, which were optimized for their light sources (a1 and b1). However, swapping the negatives and printing them with the other 'wrong' light source produced prints that were either too soft or too hard (a2 and b2). Nevertheless, adjusting the paper contrast compensated for the wrong negative contrast and produced almost indistinguishable prints with either enlarger (a3 and b3). Given the results from this test, there seems to be no justification to pick one type of enlarger over another for tonality reasons, as long as negative or paper contrast is adjusted to fit the light source (fig.6).

### Sensitometry Verification

To confirm the conclusion reached on the basis of the pictorial comparison, the test was repeated with two step tablets. This verified the assumptions made from the pictorial examples in fig.5, because the same negative printed with a condenser and a diffusion enlarger produced two prints of very different tonality. However, printing contrast-adjusted negatives on each enlarger produced an almost identical print tonality.

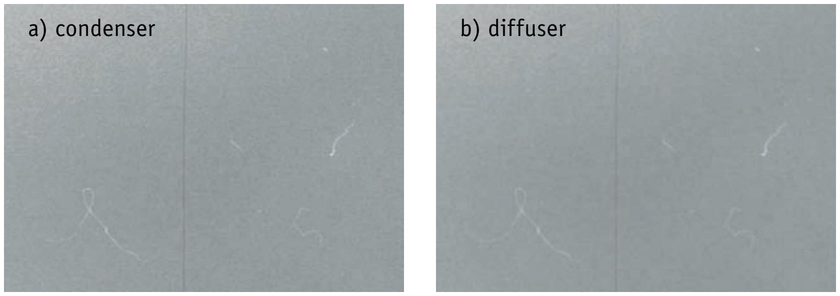
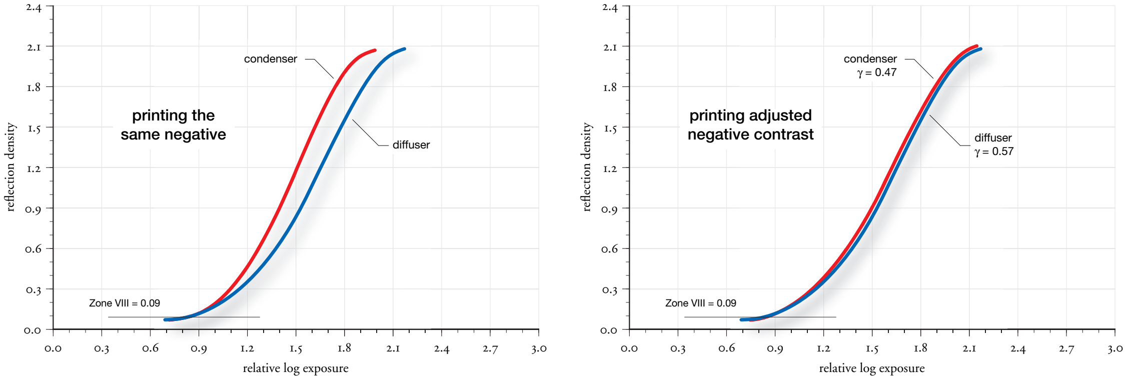


fig.7 Condenser enlargers are claimed to be sharper and to show more detail than diffusion enlargers, but they have the disadvantage of highlighting dust and scratches and require more print spotting. When compared at a 10x negative magnification, the difference is clearly detectable, but at normal viewing distance, this will not make for a more detailed print, nor will it save you from print spotting.

### Dust and Scratches

Condenser enlargers are claimed to be sharper and to show more detail than diffusion enlargers, but they have the disadvantage of highlighting dust and scratches, and requiring more print spotting. All these characteristics are based on the scatter of collimated light, which is caused by silver particles, dust and scratches alike. When compared at a 10x negative magnification, the difference between condenser and diffusion enlarger is clearly visible (fig.7). The effect increases with negative magnification, but at normal viewing distance, this will not make for a more detailed print, nor will it save you from print spotting.

There are obvious differences between condenser and diffusion enlargers when it comes to their design and handling. Condensers make more efficient use of the light source and offer a minute increase in acutance, which makes them ideal for 35mm enlargements. Diffusion enlargers reduce the need for print spotting and typically offer stepless contrast changes. But given the right negative, both are perfectly capable of producing a smooth, full-scale print.



a) Printing the same negative produces different prints.

b) Contrast-adjusted negatives produce identical prints.

fig.6 Printing two step tablets verified the conclusions made from the pictorial examples in fig.5, because the same negative printed with a condenser and a diffusion enlarger produced two prints of different tonality. However, printing contrast-adjusted negatives on each enlarger produced two prints with almost identical print tonality.

# Sharpness in the Darkroom

## Maximum resolution from corner to corner

The essentials to make the sharpest prints in a darkroom setup are well known and documented in many good photographic texts. It is surprising, therefore, that such simple advice is all too often ignored in the many darkrooms we have visited. Our recommended practices are compiled and explained here, including measured discussion on some of the myths of focusing.

### Enlarger Stability

It goes without saying that the enlarger must not wobble during the exposure. Objects can only wobble if they are unnecessarily provoked or not sufficiently constrained. If you have a permanent darkroom setup, our advice is to remove the column from the baseboard and rigidly mount it to the wall, as shown in fig.1.

This isolates the enlarger from floor and table vibrations, and enables vertical column adjustment to level the enlarger head. Wall-mounting brackets are available from some enlarger manufacturers and independent retailers. Alternatively, mount the baseboard column bracket to a rigid wall-mounted shelf, and fix the top of the column to the wall with a homemade bracket. Another benefit from using a wall-mounted enlarger is the ability to lift the column upwards and outwards, so a large printing easel fits under the column for big enlargements. A wall-mounted column must be adjusted using a small spirit level, so that the negative plane is horizontal, both side to side and front to back, as shown in fig.2. Having set up the enlarger, check the rigidity of the setup by observing the stability of the projected image with a grain magnifier.

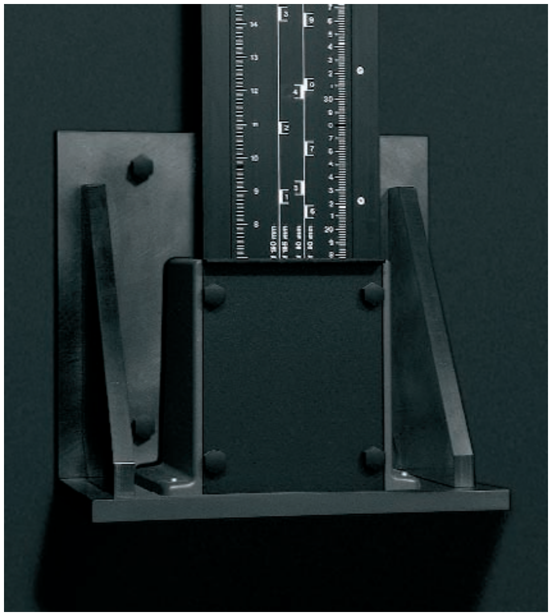


fig.1 (right) This professional Durst L1200 enlarger is wall-mounted through an aluminum bracket, which supports the enlarger's weight and isolates the column from vibration.

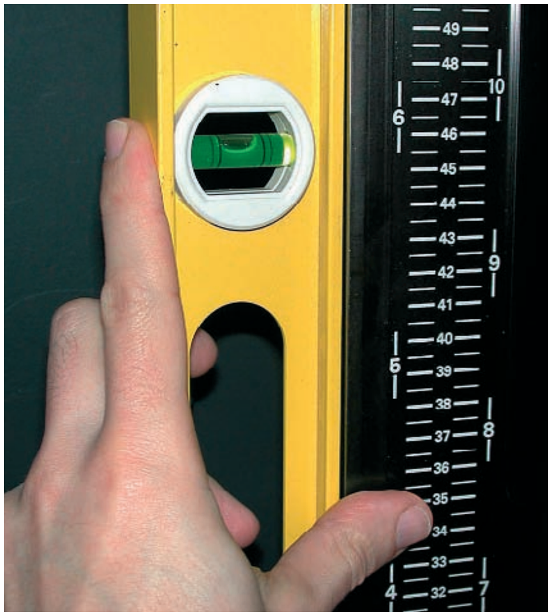


fig.2 (far right) A spirit level is used to check the vertical alignment of an LPL enlarger column.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50072-7

During the exposure, minimize the excitation of the enlarger and baseboard, especially if you are unable to wall-mount the column. If you touch the enlarger, wait for the vibrations to settle down before making an exposure, and then, be careful not to move about or touch the base unit or the table it stands on. Also, if you enjoy listening to music while working in the darkroom, make sure that the speaker boxes are not on the same table as the baseboard. Even heavy outside traffic and nearby railway lines have been known to cause problems. If you have a darkroom timer with a foot switch, use it like a cable release.

## Film Flatness

Film does not lie flat naturally. Heat, storage conditions and humidity all affect its natural curl. In the same way that a camera requires the film to be flat, so do enlargers. Glassless negative carriers do not keep the film flat. Fig.3 shows the reflection of a window frame from the film surface, which indicates how difficult it is to keep 35mm film flat in a glassless negative carrier. The problem increases with larger negatives on medium and large-format film.

We cannot rely on the depth of focus to compensate for film unevenness and secure perfect sharpness, because the room for permissible error is just too small (see fig.12). To make matters worse, as the negative warms up in the light path, it pops just as a transparency does in a slide projector. In order to ensure maximum sharpness, the film must be held absolutely flat during projection. We recommend printing the film with the emulsion side down in a negative carrier, which sandwiches the film between two sheets of glass. The extra effort of keeping the four additional glass surfaces dust-free, to avoid unreasonable print spotting, is well worth the results. Nevertheless, to keep unsightly color fringes from forming concentric rings of irregular shape between film and glass (Newton's rings), use a specially etched anti-Newton glass on top of the film, towards the shiny film base. Usually, you can use clear glass on the other, matt emulsion side of the film. However, some films, such as Ilford XP2 and the now discontinued Agfa APX25, have a very smooth emulsion side. With these films, Newton's rings can still occur between the clear glass and emulsion side of the film. If you use this type of film, remove the glass from the bottom altogether, and keep only the anti-Newton glass on top of the film.

## Enlarger Alignment

Accurate enlarger alignment is one of the less obvious requirements for sharpness in the darkroom. A misaligned enlarger does not have the baseboard, film and lens planes perfectly parallel. This is evident in the projected image as unequal grain sharpness from one corner to the next. Precise enlarger alignment can be achieved with a simple spirit level, and this method will satisfy all but the most discerning users. However, some enlarger designs prevent convenient spirit level access to film or lens plane, requiring more sophisticated alignment technology.

### Using a Spirit Level for Alignment

With the help of a spirit level, the paper, lens and negative planes are adjusted until they are horizontal and as parallel as possible.

1) The easel surface is made horizontal, both back-to-front and side-to-side, either by adjusting the feet or the entire table, possibly using spacers.
2) The wall-mounted column is adjusted vertically, side-to-side and front-to-back, so the negative stage is horizontal front-to-back, as seen in fig.2. In some cases, the customary holes for wall-mounting screws may need to be filed into slots, to enable adjustment of the top and bottom column brackets.
3) Assuming the enlarger head has a tilt feature, adjust it so the negative stage is horizontal, side-to-side. If the head is fixed, then the column will need further adjustment to counteract the error.
4) Lastly, the spirit level is held against the front face of the enlarging lens and the lens stage is leveled, either by the available adjustments or by inserting a spacer into the mechanism.

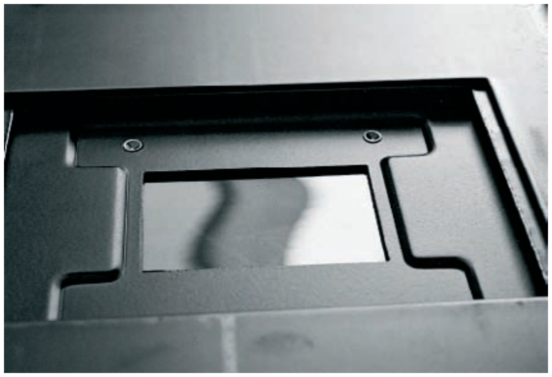


fig.3 This close-up of a glassless 35mm negative carrier clearly indicates an uneven film surface, seen in the reflection of a nearby window frame.

fig.4 A small laser module can be bought from any electronic shop for the price of a few films. To turn it into a self-made laser alignment tool, a housing with a leveling feature has to be made, and the leads have to be connected to a power supply. A detailed technical drawing for a potential implementation is found under ‘Tables and Templates’ in the appendix.

### Constructing a Laser Alignment Tool

A simple laser module can be bought for the cost of a few rolls of film from any good electronic shop (fig.4). With a little ingenuity, it can be fashioned into a useful alignment tool by gluing it into a machined metal cylinder, which in this case was manufactured according to the sketch in fig.5a. Three tapped holes were added to the base of the cylinder to accept small adjustment screws, which assure the laser beam is perfectly vertical when the housing is placed on a horizontal surface. The screws level the laser alignment tool, using the following procedure:

Place the laser alignment tool on the baseboard, and use two heavy objects to form a corner, so that when the alignment tool is rotated, while being pushed into the corner, the center of the laser remains in a fixed position. As the tool is turned, note the position of the laser beam on the ceiling, using some masking tape and a pen. Initially, the laser will trace out a small circle. Turn one or two of the adjustment screws, until the beam aims at the center of this circle. When the adjustment is accurate, the red light spot appears stationary during rotation of the tool. Having calibrated the laser alignment tool, the screw positions can be fixed with a little varnish.

### Using a Laser Alignment Tool

If you prefer a professionally made enlarger alignment unit to the self-made variety, we recommend that you check into the ‘zig-align’ system or the ‘Parallel’ alignment gage made by Versalab. They can be purchased for the price of a good enlarging lens.

It is sensible to start the laser alignment process with a previously leveled easel and a vertically aligned column. Turn the laser on, making sure to never point it at someone’s eyes, and adjust negative and lens stage in sequence as follows, while judging the results according to the instructions in fig.6.

1) Raise the enlarger head to the top of the column and lock it as you would during normal operation. Remove the enlarger lens, and place the laser alignment tool directly beneath the opening just created. Adjust the negative stage until the laser beam’s reflection from the negative-carrier glass aims back at the laser exit hole as closely as possible.
2) Return the enlarger lens, and with a filter fitted to its attachment ring or a piece of glass just held against its front surface, adjust the lens stage until the laser beam reflects back on itself, which indicates that it is parallel to the baseboard.

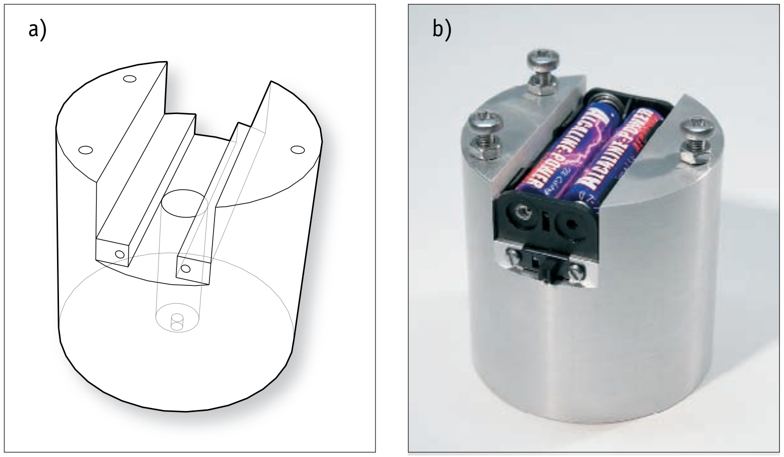


fig.5a&b With some ingenuity and help from a local machine shop, a self-made laser alignment tool is brought from concept to reality. Three adjustable screws level the unit and align the laser module until it projects a perfectly vertical laser beam.

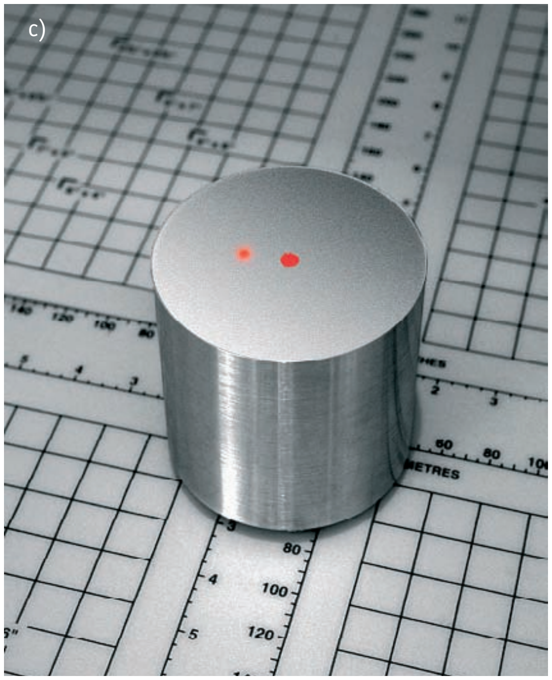


fig.5c The finished laser alignment tool is leveled on the baseboard and placed directly under the enlarger. The laser is then made to reflect off the negative carrier and the lens plane. The location of the reflected laser beam is a measure of misalignment.

### Centering the Lens

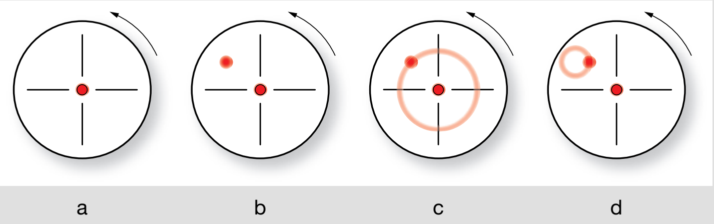
Whichever alignment method you use, it is essential to check that the lens axis is centered in the negative area. To do this, take a fogged negative leader, the same format as your negative carrier, and scratch in two diagonal lines to locate the middle. Center and project this negative on to the easel. Mark the intersection on the easel, and check that this point does not travel across the easel as the head is moved up and down the column. Use the horizontal adjustment mechanism on the lens stage to centralize the lens. After any adjustment, confirm the lens alignment with a spirit level or the laser alignment tool.

## Enlarging Lens

It is pointless to use the best camera lens if the print is let down by a poorly performing, cheap enlarging lens. There are many manufacturers of quality optics, Nikon, Schneider and Rodenstock to name but a few, and excellent used Leica and Minolta lenses are available. As with many products, the purchase price is an indicator, but not a guarantee, of the quality of a particular enlarging lens. However, you can minimize the risk by selecting a name-brand, high-quality, six-element, multi-coated lens. This is most likely to ensure high performance in the 4-12x range of enlargements. Nevertheless, several authors have reported that manufacturing tolerances within a brand can vary more than from brand to brand. It is a big advantage, therefore, to buy your lens from an understanding dealer, who lets you check its performance against others.

The optical performance of any lens changes with aperture. Enlarging lenses are no different. An optimum aperture is the best compromise between overall resolution, even illumination and exposure time. For many lenses, the optimum aperture is between f/5.6 and f/11. Keen observation, and some trial and error, will determine your ideal setting for each lens. Having found your ideal setting, try to use this aperture for all your printing, rather than using a constant printing time. After aligning the enlarger, your prints should be grain sharp, in the middle and equally at each corner. At the same time, a print made without a negative in the carrier and printed mid-gray on high-contrast paper should confirm even illumination.

If you use small-format negatives and enlarging lenses in a large-format enlarger, it is critically



To judge the enlarger alignment, rotate the laser and watch the reflected beam. The examples above illustrate how you can tell if the enlarger is out of alignment or if the laser beam is just not perpendicular to the baseboard.

a) The reflected beam stays centered on the target. This indicates that the laser is perpendicular, and the reflecting surface is parallel to the baseboard.
b) The reflected beam is not on center, but it does not move as the laser is rotated. This indicates that the laser is perpendicular, but the reflecting surface is not parallel to the baseboard.
c) The reflected beam is not on center, but it creates a concentric circle around the target as the unit is rotated. This indicates that the laser is not perpendicular, but the reflecting surface is parallel to the baseboard.
d) The reflected beam is not on center and it follows a circular path not centered on the target. This indicates that the laser is not perpendicular, and the reflecting surface is not parallel to the baseboard. If the laser is adjusted closer to perpendicular, the circular path will get smaller until it matches condition 'b'. If the reflecting surface is aligned to be more parallel to the baseboard, the path of the beam will become concentric with the laser orifice and eventually approaches condition 'c'.

Good enlarger alignment is indicated by condition 'a' and 'c'.

EL-NIKKOR 80mm 1:5.6 MADE IN JAPAN
6" x 4"

fig.6 (top) There is an easy way to tell if the enlarger is out of alignment, or if the laser beam is simply not perpendicular to the baseboard.
(text & illustration by Dale H. Marsh)

fig.7 (left) The purchasing price of a particular enlarging lens is an indicator, but not a guarantee, of its quality. However, you can minimize the risk by selecting a name-brand, high-quality, six-element, multi-coated lens.

fig.8 Although this picture of Chris's daughter, Katie, is taken at full aperture with the Fuji 680 and, consequently, has a shallow depth of field, it requires corner-to-corner sharpness to ensure crisp grain over the entire print.

important to place the negative centrally in the negative carrier. The enlarging lens is designed for a certain maximum coverage and the illumination and sharpness degrade quickly outside these boundaries. In our enlargers, we use a film format template, cut from thin black plastic, which we place on the negative carrier's top glass. It was made such that the outer dimensions snugly fit inside the glass frame's inner edges. Once the outer dimensions of the template are trimmed, slightly oversized negative dimensions are centralized and cut out with a sharp knife.

#### Paper Flatness

Fiber-base papers, and, to some extent, resin-coated papers, suffer from curl and unevenness. We have observed the curl of a piece of paper changing, when placed unrestricted on a flat surface and left to relax for a minute, as it adjusts to the humidity and temperature of its new surroundings. These movements can cause a loss of sharpness, especially towards the borders of the print, as the horizontal creep during the exposure blurs the image. However, a two or four-blade easel holds down the paper satisfactorily. To make borderless prints, simple side restraint easels suffice. If you do not use an easel, attach double-sided, low-tack adhesive tape directly to the baseboard. The tape is applied to the baseboard, and the print is pressed slightly against the tacky surface. This tape has a similar adhesive quality to the one used on 3M 'Post-it' notes, and, although tacky, it does not damage the print when lifted off the baseboard.

However, as long as the paper lies still, there is no need to be overly concerned about paper flatness. Depth of field covers a significant distance at the baseboard, especially with small film formats. An 8x10-inch enlargement, projected at a working aperture of f/8, from a full 35mm, 6x6 and 4x5 negative will have a depth of field of 28, 17 and 9.3 mm, respectively (see fig.12). This should disprove the myth that a single piece of photographic paper, with a thickness of just 10 mil (0.25 mm) and placed under the focus finder, will improve accurate focusing and print sharpness.

### Accurate Focusing

Our prints have often been complimented on their excellent sharpness, and yet, our darkroom procedures are common and simple. We just focus the image at full aperture using white light, and then, stop down to the working aperture before printing. Since our results are of high quality, there was really no need to explore other alternatives. Nevertheless, while researching for this book, we uncovered a volume of opinion on numerous effects claiming to cause focusing errors, with considerable disagreement between authors. Out of interest, we have evaluated the significance of some of these effects, including ultraviolet paper sensitivity, focusing with filtered light and focusing at the working aperture.

#### Ultraviolet Paper Sensitivity

Ultraviolet radiation has a wavelength below 380 nm, and although enlarging lenses transmit this radiation, they are rarely corrected for the chromatic aberration below 400 nm. The data sheets from Agfa, Ilford and Kodak indicate that the spectral sensitivity of their B&W papers extends well into the ultraviolet range.

Consequently, ultraviolet radiation reduces print sharpness, since the paper is sensitive to it, and the lens is not corrected for it. An ultraviolet filter (1A) has a transmittance of only 1% below 380 nm. This filter, placed below the enlarging lens, yields a sharper print but reduces the effective print exposure, if ultraviolet radiation is present in significant quantities.

In practice, the insertion of an ultraviolet filter into the, otherwise unfiltered, light path of a tungsten-halogen enlarger made no detectable difference to an Agfa Multicontrast RC print, neither in print density nor in sharpness. The conclusion that the tungsten bulb emits no significant quantities of ultraviolet radiation was confirmed by the bulb manufacturer's data sheet. A cold cathode head, whose light source uses fluorescent materials, is blue and ultraviolet rich, and therefore poses a greater potential problem. The use of an ultraviolet filter, in this case, may greatly reduce the effective exposure to UV radiation. Unfortunately, each lens, paper and enlarging light system may have its own unique focus error, ranging from minuscule to significant. Comparing two prints made with and without the use of a UV filter will identify whether you need to take corrective actions.

### Focusing with Filtered Light

Patrick Gainer wrote an article titled 'Hazards of the Grain Focuser' for *Photo Techniques* Jan/Feb 1997, which explained the chromatic aberrations of the enlarger, an aerial grain focuser and the human eye. His thorough investigation used a simple series of optical experiments to clearly show the inability of the human eye, enlarger lens and the grain focuser to focus at several wavelengths simultaneously.

We repeated these experiments and arrived at similar conclusions. The expectation that optimum focusing occurs only if we focus with contrast filters in place was disproved. We found that focusing with different contrast filtration made little difference to print sharpness, and prints from 10x enlarged negatives could only be distinguished with an 8x loupe. In fact, the ability of any individual to focus consistently is more of an issue than the choice of filtration.

Some grain focusers (fig.9) provide a blue filter to focus only on the wavelength of light most sensitive to the paper. Unfortunately, the human eye is not very sensitive to blue light and the resulting image is dim and difficult to see. In our tests, this method suffered the maximum human focus variability. Patrick Gainer's simple recommendation is to focus without contrast filters in place, and we agree that print focusing is best done with the unfiltered white light of the enlarger. This does not constitute any additional effort, because enlarger light metering must be done without contrast filtration anyway. Nevertheless, critical print sharpness is more likely to be affected by vibration, film flatness and enlarging lens quality than filtration.

### Focusing at the Working Aperture

Another popular 'tip' is to focus at the working aperture of the enlarger lens. As the lens is stopped down, the optical aberrations of the lens, and therefore, its sharpness, improves down to the aperture at which the lens performance is diffraction limited. The assumption is that the best focus is obtained with the sharpest projected image. In addition, a low quality lens may suffer from focus-shift, where the focal length of the lens slightly changes with aperture.

A practical test, using any of our high-quality, six-element lenses, showed that there was no repeatable difference between focusing at full aperture or at the working aperture of f/8. However, as with the dark

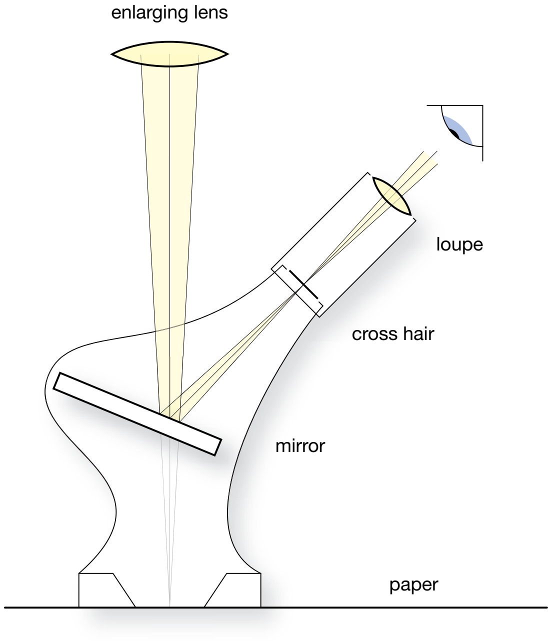


fig.9 Focusing aids compare the aerial image reflected from a mirror with a built-in cross hair. The cross hair is in a fixed position so the length of the light path from negative to cross hair is the same as that from negative to easel. The cross hair is brought into sharp focus by adjusting the loupe, and then, the image is brought into sharp focus by adjusting the enlarger.

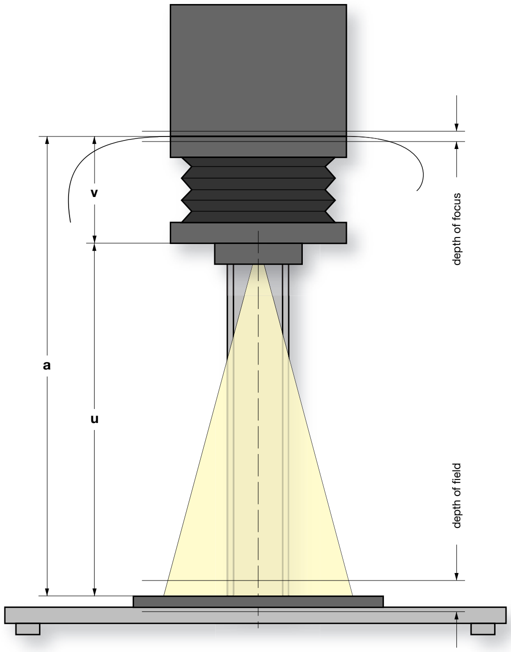


fig.10 (right) As there is a zone of reasonable focus surrounding the paper plane, known as the depth of field, there is an equivalent zone of reasonable focus surrounding the negative plane, called the depth of focus.

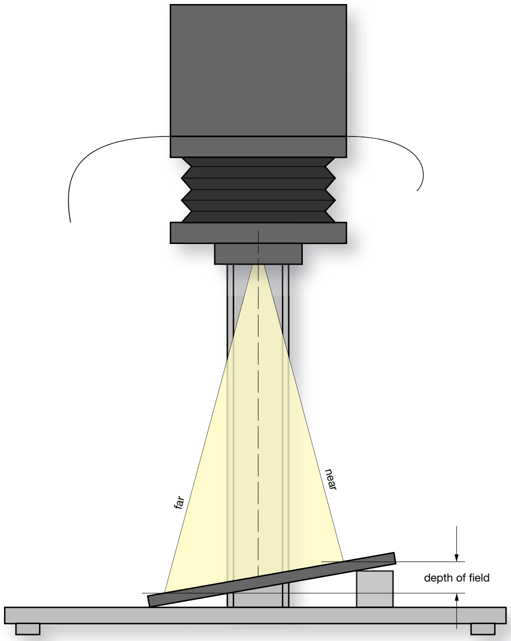


fig.11 (far right) Taking advantage of the depth of field, minor perspective distortions can be corrected through a baseboard lift without losing reasonable sharpness.

| format | depth of focus [mm] | | | | depth of field [mm] | | | |
|---|---|---|---|---|---|---|---|---|
| 24x36 c = 0.022 | 4 | 5.6 | 8 | 11 | 4 | 5.6 | 8 | 11 |
| 8x10 | 0.2 | 0.3 | 0.4 | 0.5 | 14 | 20 | 28 | 39 |
| 11x14 | 0.2 | 0.3 | 0.4 | 0.5 | 27 | 37 | 53 | 73 |
| 16x20 | 0.2 | 0.3 | 0.4 | 0.5 | 53 | 75 | 110 | 150 |
| 6x6 c = 0.042 | 5.6 | 8 | 11 | 16 | 5.6 | 8 | 11 | 16 |
| 8x10 | 0.6 | 0.8 | 1.1 | 1.6 | 12 | 17 | 23 | 33 |
| 11x14 | 0.5 | 0.8 | 1.1 | 1.6 | 22 | 31 | 42 | 62 |
| 16x20 | 0.5 | 0.7 | 1.0 | 1.5 | 43 | 62 | 85 | 120 |
| 4x5 c = 0.089 | 5.6 | 8 | 11 | 16 | 5.6 | 8 | 11 | 16 |
| 8x10 | 1.5 | 2.1 | 2.9 | 4.2 | 6.5 | 9.3 | 13 | 19 |
| 11x14 | 1.3 | 1.9 | 2.6 | 3.8 | 11 | 16 | 22 | 32 |
| 16x20 | 1.2 | 1.8 | 2.4 | 3.5 | 22 | 31 | 43 | 62 |

fig.12 depth of field and focus for several formats and f/stops

blue filter, it was difficult to focus the dim image consistently, and we concluded that it was more likely that this would cause the observer to introduce a focus variability. In addition, any minor focusing errors, still visible at full aperture, are easily lost in the depth of field at smaller working apertures.

### Mural Prints

While many of the error mechanisms mentioned above cause little difference to effective print sharpness for small and medium enlargements, mural prints must be considered a special case. Focus and sharpness issues add up, and therefore, critical big enlargements require special care. By all means, conduct your own focus experiments, using different apertures, focus finders and test prints, to establish optimum working conditions. However, take every possible precaution with big enlargements to reduce enlarger vibrations to an absolute minimum.

## Depth of Field and Focus

In the chapter 'Sharpness and Depth of Field' we illustrate how, when taking a photograph, the circle of confusion creates zones of reasonable focus around the subject and the film plane, called depth of field and focus, respectively. The sample principle creates similar zones around the negative and the paper plane when the image is projected by the enlarger (fig.10). In each case, the term 'depth of focus' is reserved for the film or negative side of the optical path, whereas the term 'depth of field' is commonly used for the subject or the projection side. The depth of focus ($d_{F'}$) and the depth of field ($d_F$) can be calculated as:

$$d_{F'} = 2 \cdot c \cdot N \cdot \left(1 + \frac{1}{m}\right)$$

$$d_F = 2 \cdot c \cdot N \cdot \left(1 + \frac{1}{m}\right) \cdot m^2$$

where 'c' is the circle of confusion, 'N' is the aperture of the enlarging lens in f/stops and 'm' is the print magnification of the enlargement. Fig.12 shows typical values, calculated with the equations above.

Both equations assume that the print magnification of the enlargement is already known, and it is good practice to document the printing scale with your printing records. The actual print magnification is simply found by cutting two notches, 1 inch apart, into the negative mask (fig.13) and measuring their projected distance on the baseboard with a ruler.

For the more mathematically inclined, print magnification (m) can also be determined from the basic dimensions of the enlarger setup and calculated as:

$$m = \frac{u}{v} \quad = \frac{u}{f} - 1 \quad = \frac{f}{v - f}$$

$$m > 1 = \frac{\left(\frac{a}{f} - 2\right) + \sqrt{\left(\frac{a}{f} - 2\right)^2 - 4}}{2}$$

$$m < 1 = \frac{\left(\frac{a}{f} - 2\right) - \sqrt{\left(\frac{a}{f} - 2\right)^2 - 4}}{2}$$

where ‘u’ is the lens-to-paper distance, ‘v’ is the lens-to-negative distance, ‘a’ is the total negative-to-paper distance, ‘f’ is the focal length of the lens, while ‘m>1’ calculations are meant for enlargements and ‘m<1’ for reductions. Strictly speaking, lens distances are measured to the nodal plane of the lens, but the center of the lens will suffice as a practical substitute.

For some photographic applications, it may be of interest to adjust the enlarger setup in order to produce a specified print magnification, and, in fact, the equations below are a reverse of the above formulae.

$$u = f \cdot (m + 1) \quad = \frac{a + \sqrt{a^2 - 4 \cdot f \cdot a}}{2}$$

$$v = f \cdot \left(1 + \frac{1}{m}\right) \quad = \frac{a - \sqrt{a^2 - 4 \cdot f \cdot a}}{2}$$

$$a = u + v$$

$$a = \frac{f \cdot (m + 1)^2}{m}$$

During in-camera focusing, the zone around the subject plane (depth of field) is commonly understood as a zone of reasonable sharpness and, therefore, as an extension to what theoretically is only a plane of focus. On the other side of the imaging path, the depth of focus at the camera’s film plane is typically considered to be a tolerance band for mechanical focusing inaccuracies. While the former is true, the latter is not entirely the case. As seen in fig.14a, any focus inaccuracy at the film plane will take away from the depth of field, because any deviation from the theoretical film plane position will push subject detail, recorded at the threshold of sharpness, into defined fussiness.

Similar is true when enlarging the negative (fig.14b). Any subject point, captured at the threshold of sharpness, is recorded on the negative as a small fuzzy disc with the same diameter as the circle of confusion. During negative projection, this detail must line up exactly with the theoretical negative plane or the small disc will ‘grow’ beyond the boundaries of the circle of confusion and into obvious unsharpness.

Nevertheless, just as the depth of field provides a zone of sharpness around the subject plane when recording the subject on film, it also provides a zone of sharpness around the baseboard when projecting the negative with the enlarger. As seen in fig.11, this can be used to tilt the baseboard within limits, without losing reasonable sharpness, and allowing correction of minor perspective distortions in the negative. In practice, the image center is brought into focus at full aperture, and the lens is stopped down until the entire image appears to be in focus. You can use the table in fig.12 to estimate the available depth of field for several formats and apertures.

### The Scheimpflug Principle

The Austrian cartographer and sea captain Theodore Scheimpflug (1865 - 1911) is credited with the discovery of the optical relationship, which now carries his name. If a camera is adjusted so the film, lens and subject plane intersect in a single line, then everything in the subject plane will be in perfect focus. View cameras can be adjusted to take advantage of the Scheimpflug principle, but cameras with fixed film and lens planes cannot. Therefore, any perspective distortion unavoidably becomes a permanent part of the negative and can only be corrected in the darkroom.

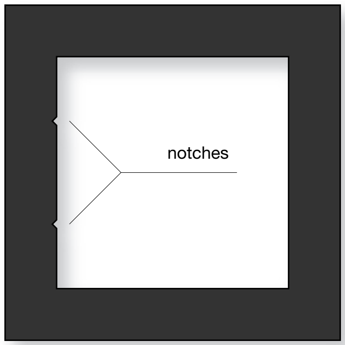


fig.13 The actual print magnification is simply found by cutting two notches, 1 inch apart, into the negative mask and measuring their projected distance on the baseboard with a ruler.

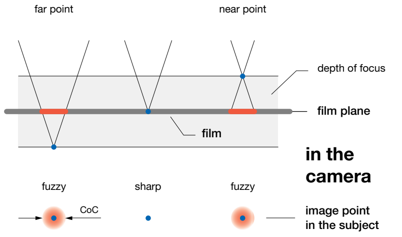


fig.14a Any subject point, captured on film at the threshold of sharpness, is recorded as a reasonably sharp fuzzy disc the size of the CoC.

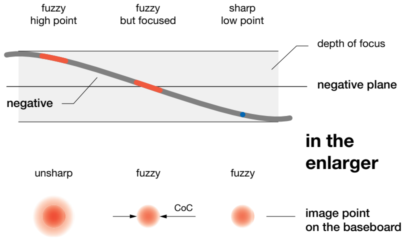


fig.14b Negative detail as large as the CoC must exactly line up with the theoretical negative plane, or it is not resolved in the print. Only perfectly sharp negative detail can benefit from the enlarger’s depth of focus.

fig.15 Many enlargers allow only tilting of the lens plane, but with the help of a tilted easel, converging lines can be completely corrected using the Scheimpflug principle. This results into a projection geometry, which is identical to that of a fully adjustable enlarger, as seen in fig.17.

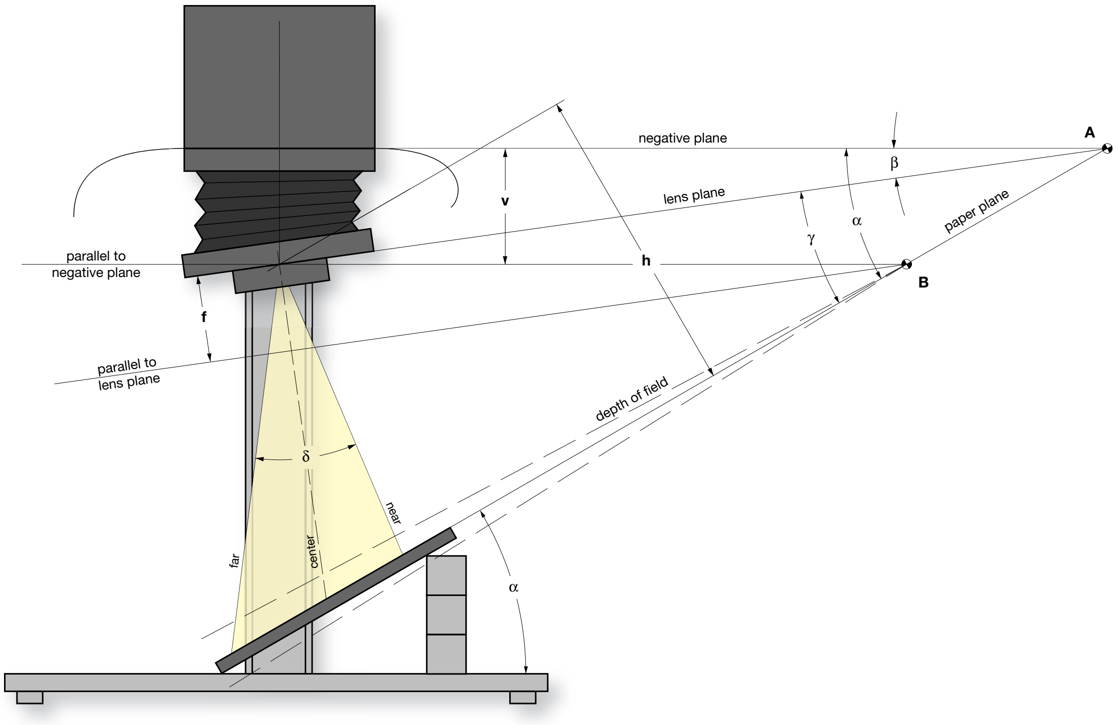

negative plane
A
β
lens plane
α
γ
paper plane
B
v
h
parallel to negative plane
f
parallel to lens plane
depth of field
δ
near
far
center
α

fig.16 This photograph of Ingatestone Church in Essex, UK was taken with a 35mm Canon SLR. In order to get the entire structure into the frame, the camera had to be pointed upwards, creating unwanted, but unavoidable, perspective distortion and converging lines, as seen in the straight print on the left. The corrected print on the right was made from the same negative, but the perspective distortion was corrected until the vertical lines of the church tower appeared to be parallel. In the upper half, the actual print was gradually burned-in to compensate for the exposure loss caused by the head tilt. (images by Paul Robbins)

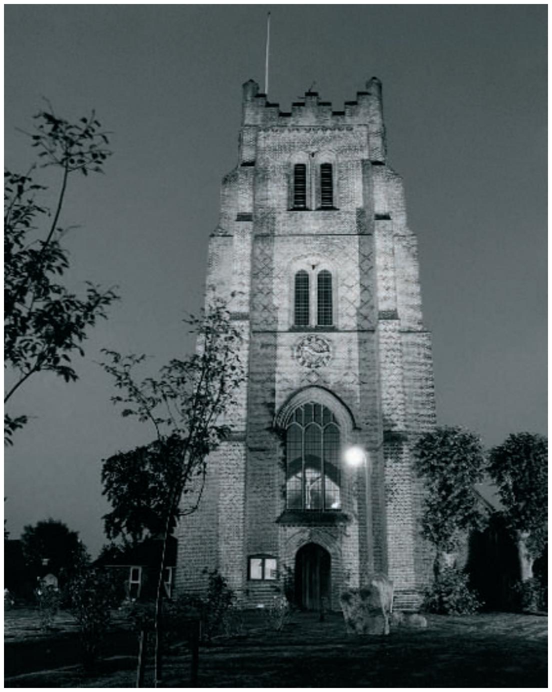


fig.16a converging lines not corrected

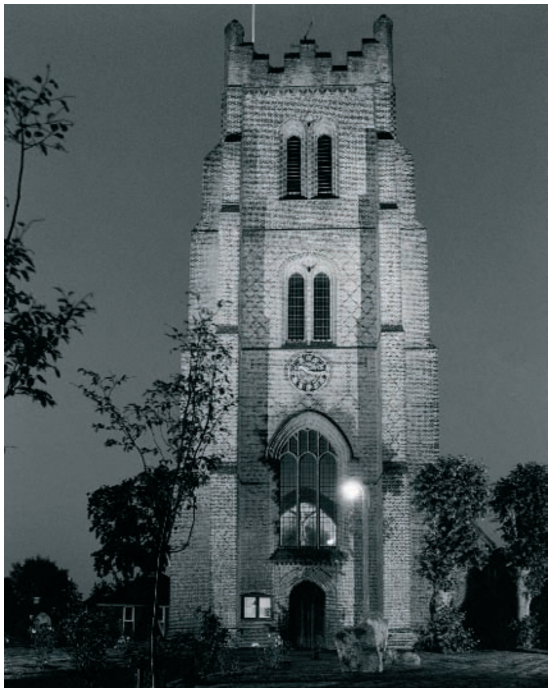


fig.16b converging lines corrected

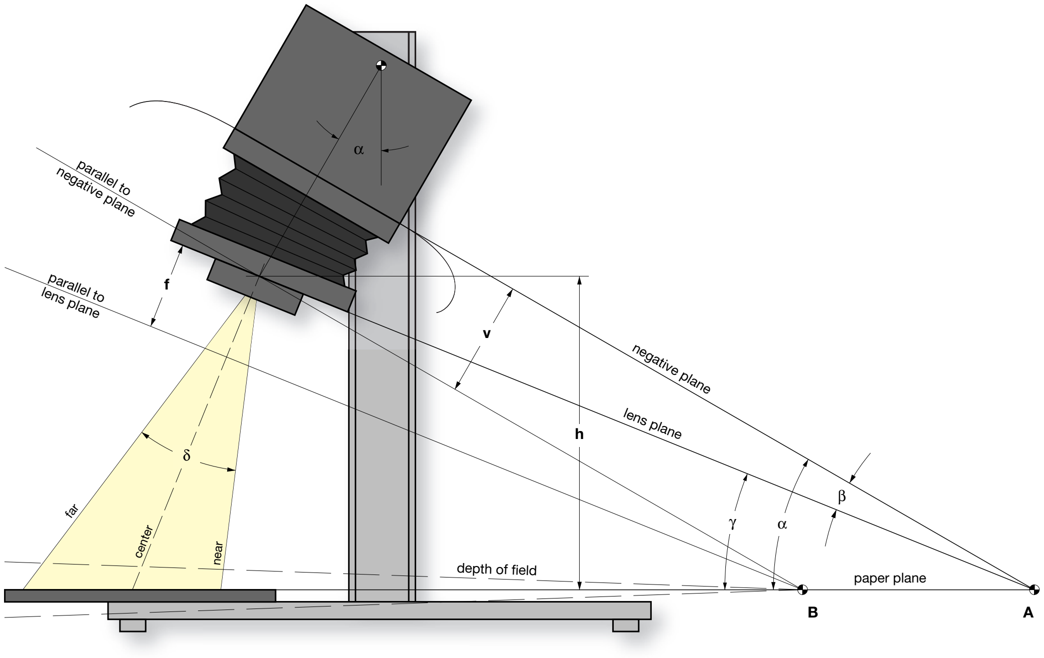


fig.17 Professional enlargers feature full 'Scheimpflug' correction capabilities similar to view cameras. If such an enlarger is adjusted so the negative, lens and paper planes intersect in a single line, then the entire image will be in perfect focus. This technique eliminates perspective distortions, also called converging lines, at the printing stage. The setup involves a three-step process and may require some exposure correction on the 'near' and 'far' side.

| β | | f = 50 mm | | | | | | f = 80 mm | | | | | | f = 105 mm | | | | | | f = 150 mm | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | α | 5 | 10 | 15 | 20 | 25 | 30 | 5 | 10 | 15 | 20 | 25 | 30 | 5 | 10 | 15 | 20 | 25 | 30 | 5 | 10 | 15 | 20 | 25 | 30 |
| h | 200 | 1.2 | 2.5 | 3.7 | 4.9 | 6.0 | 7.1 | 2.0 | 4.0 | 5.9 | 7.8 | 9.6 | 11 | 2.6 | 5.2 | 7.7 | 10 | 13 | 15 | 3.7 | 7.4 | 11 | 14 | 18 | 21 |
| | 300 | 0.8 | 1.7 | 2.5 | 3.3 | 4.0 | 4.8 | 1.3 | 2.7 | 3.9 | 5.2 | 6.4 | 7.6 | 1.7 | 3.5 | 5.2 | 6.8 | 8.4 | 10 | 2.5 | 5.0 | 7.4 | 9.7 | 12 | 14 |
| | 400 | 0.6 | 1.2 | 1.9 | 2.4 | 3.0 | 3.6 | 1.0 | 2.0 | 3.0 | 3.9 | 4.8 | 5.7 | 1.3 | 2.6 | 3.9 | 5.1 | 6.3 | 7.5 | 1.9 | 3.7 | 5.5 | 7.3 | 9.0 | 11 |
| | 500 | 0.5 | 1.0 | 1.5 | 2.0 | 2.4 | 2.9 | 0.8 | 1.6 | 2.4 | 3.1 | 3.9 | 4.6 | 1.0 | 2.1 | 3.1 | 4.1 | 5.1 | 6.0 | 1.5 | 3.0 | 4.4 | 5.9 | 7.2 | 8.5 |
| | 600 | 0.4 | 0.8 | 1.2 | 1.6 | 2.0 | 2.4 | 0.7 | 1.3 | 2.0 | 2.6 | 3.2 | 3.8 | 0.9 | 1.7 | 2.6 | 3.4 | 4.2 | 5.0 | 1.2 | 2.5 | 3.7 | 4.9 | 6.0 | 7.1 |
| | 700 | 0.4 | 0.7 | 1.1 | 1.4 | 1.7 | 2.0 | 0.6 | 1.1 | 1.7 | 2.2 | 2.8 | 3.3 | 0.7 | 1.5 | 2.2 | 2.9 | 3.6 | 4.3 | 1.1 | 2.1 | 3.2 | 4.2 | 5.2 | 6.1 |
| | 800 | 0.3 | 0.6 | 0.9 | 1.2 | 1.5 | 1.8 | 0.5 | 1.0 | 1.5 | 2.0 | 2.4 | 2.9 | 0.7 | 1.3 | 1.9 | 2.6 | 3.2 | 3.8 | 0.9 | 1.9 | 2.8 | 3.7 | 4.5 | 5.4 |
| | 900 | 0.3 | 0.6 | 0.8 | 1.1 | 1.3 | 1.6 | 0.4 | 0.9 | 1.3 | 1.7 | 2.2 | 2.5 | 0.6 | 1.2 | 1.7 | 2.3 | 2.8 | 3.3 | 0.8 | 1.7 | 2.5 | 3.3 | 4.0 | 4.8 |
| | 1,000 | 0.2 | 0.5 | 0.7 | 1.0 | 1.2 | 1.4 | 0.4 | 0.8 | 1.2 | 1.6 | 1.9 | 2.3 | 0.5 | 1.0 | 1.6 | 2.1 | 2.5 | 3.0 | 0.7 | 1.5 | 2.2 | 2.9 | 3.6 | 4.3 |

| $^1/_{12}$ f/stop | δ = 40° | | | | | | δ = 45° | | | | | | δ = 50° | | | | | | δ = 55° | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| γ = α–β | 5 | 10 | 15 | 20 | 25 | 30 | 5 | 10 | 15 | 20 | 25 | 30 | 5 | 10 | 15 | 20 | 25 | 30 | 5 | 10 | 15 | 20 | 25 | 30 |
| far | +1 | +2 | +4 | +5 | +6 | +8 | +1 | +3 | +4 | +6 | +7 | +9 | +1 | +3 | +5 | +6 | +8 | +11 | +2 | +3 | +5 | +7 | +10 | +12 |
| near | -1 | -2 | -3 | -4 | -5 | -7 | -1 | -2 | -4 | -5 | -6 | -7 | -1 | -3 | -4 | -5 | -7 | -8 | -2 | -3 | -5 | -6 | -8 | -9 |
| total | 2 | 4 | 7 | 9 | 12 | 15 | 2 | 5 | 8 | 11 | 14 | 17 | 2 | 6 | 9 | 12 | 15 | 19 | 3 | 6 | 10 | 13 | 17 | 21 |

fig.18 These two tables aid in determining the initial lens tilt 'β' (top) and exposure correction according to the angle between lens and paper 'γ' (bottom). Measure the lens to paper distance 'h' and the head tilt 'α'. Find the lens tilt 'β' for your focal length in the top table. Calculate the angle between lens and paper from γ=α–β, and use the bottom table to find the exposure correction, relative to the centerline, in 1/12-stop increments for the near and the far side of projection, depending on your enlarging lens' angle of coverage 'δ'.

Some enlargers are equipped to fully support the Scheimpflug principle. If the enlarger is adjusted so the negative, lens and paper plane intersect in a single line, then the entire projected image will be in perfect focus. In the same manner as view cameras, this technique is used to eliminate perspective distortions, also known as converging lines (fig.16). A professional setup (fig.17) permits tilting of negative and lens plane independently and involves a three-step process.

1) Raise the enlarger head to 'h' to get the desired print size and focus.
2) Tilt the enlarger head to 'α' until the perspective distortion is eliminated and, otherwise, converging lines appear parallel. Refocus the image center, and estimate the location 'A' of the theoretical intersection between negative plane and paper plane.
3) Now, use fig.18 to estimate and adjust the angle of the lens plane to 'β' until it also intersects at 'A'. Check with a focusing aid, and make the necessary correction to the lens plane until corner-to-corner focus is achieved.

It takes a bit of experience to get the last step correct, but estimating the initial lens plane adjustment can be made easier using the top table in fig.18. Unfortunately, this leaves yet another problem. The distance between negative and paper is greater on the far side than it is on the near side. This gradually increases the magnification towards the far side and corrects the perspective distortion, but it also creates uneven paper illumination. Depending on the angle between lens and paper ($\gamma = \alpha - \beta$), and the coverage of the lens, this difference of illumination may be significant and easily visible in the final print. A gradual burning down from the near towards the far side will correct for the light loss. A test strip will determine the amount of exposure correction required, or you can use the bottom table in fig.18 as a starting point.

Unfortunately, few enlargers feature the flexibility to adjust negative and lens plane independently, but many allow tilting of the lens plane, as seen in fig.15. In this case, tilt the easel, while the negative is projected onto the paper, until the converging lines appear to be parallel. This will throw the image out of focus, but tilting the lens plane will correct it. Correct lens tilt and focus until the entire image is in perfect focus. At that point, the projection geometry is identical to that of a fully adjustable enlarger, with the same need for exposure correction. This setup is less convenient than the enlarger adjustments in fig.17, and precise easel tilt is not always possible, but it is still a big help in correcting converging lines.

## Exposure Height and Exposure Correction

Whenever the enlarger head is raised or lowered, and the negative magnification is changed, print exposure must be corrected. In 'Tables and Templates', you will find a chart to determine the magnification of your enlargement and another to estimate the exposure compensation required to accommodate a change in enlarger height. Strictly speaking, projected print exposures fail to follow the inverse-square law, but they follow the inverse square of the lens-to-paper distance if the paper reciprocity failure is ignored, in which case, a new theoretical exposure time ($t_2$) is given by:

$$\frac{t_2}{t_1} = \left( \frac{u_2}{u_1} \right)^2 = \left( \frac{m_2 + 1}{m_1 + 1} \right)^2$$

$$t_2 = t_1 \cdot \left( \frac{u_2}{u_1} \right)^2$$

$$t_2 = t_1 \cdot \left( \frac{m_2 + 1}{m_1 + 1} \right)^2$$

where '$u_1$' and '$u_2$' are the old and new lens-to-paper distances, '$m_1$' and '$m_2$' are the old and new magnifications, and '$t_1$' is the old exposure time.

Both charts in the appendix illustrate the optical relationships and eliminate the need for any calculations. Of course, if you are using a darkroom meter to measure print exposures anyway, you probably never need the charts or the math to ascertain a new exposure time when changing the enlarger height.

## A Sharper Image

The recommendations in this chapter have covered all fundamental variables of print sharpness, as they exist in the darkroom. A well-aligned, stable and undisturbed enlarger, holding a flat negative and projecting it with a well-focused, high-quality lens, at its optimum aperture setting, onto motionless flat paper, will result in the sharpest print possible.

# Other Darkroom Equipment

## A few useful tools, making darkroom work a lot easier and more consistent

Following on from our overview of fundamental and useful image-taking equipment, we have several items that we both consider helpful for film and print processing. Before we proceed, it is worth mentioning the obvious fact that better equipment does not necessarily lead to better results. Fancy equipment cannot replace the skill of successful image composition or a thorough understanding of the underlying principles of photography, and it cannot make up for the lack of experience. Before one succumbs to temptation, one should realize that, unless you apply a little self-discipline, the variability introduced by any number of physical or human deviations will undermine the benefits of most equipment upgrades. This does not presume a darkroom should take on the mantle of a rocket-science lab, but a little consistency, record taking and patience offer far more benefits than the latest-and-greatest electronic equipment.

(image courtesy of the Billericay Library, Essex, UK)

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50073-9

Darkrooms are creative and practical environments. Their designs and equipment differ according to individual working practices and preferences. Some photographers go for the most rudimentary equipment and the hands-on approach, while others prefer high-tech sophistication and mechanization. This introduction includes equipment to support both approaches. We have used all items shown here, at one time or another, and some are permanent elements of our current darkroom arsenal.

## Film and Print Processing

### Film Processor

For many years, we processed films by hand in a simple tank and at ambient temperatures, using an intermittent inversion technique. There is nothing wrong with this method, and, in some cases, it is actually the best way to develop a film. Stand-development to achieve the highest possible acutance is one example for the need of manual development. However, if you develop larger quantities of film on a regular basis, and you want to do it with consistency, it may be worth checking into an automatic film processor. A popular model among amateurs is the Jobo CPE-2 processor (fig.1a), which conveniently controls agitation and temperature for print and film development. It is basically a plastic tub that holds a thermostatically controlled water bath and a development tank, which is kept in motion by an alternating bidirectional rotation system.

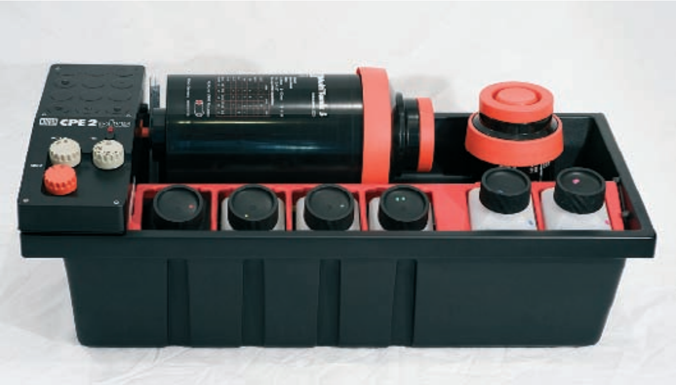


fig.1a A popular piece of equipment among amateurs is the Jobo CPE-2 processor, which conveniently controls agitation and temperature for color or monochrome print and film development.

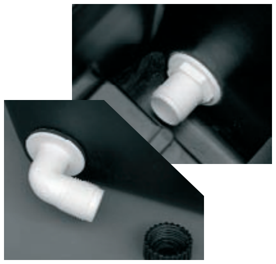


fig.1b Filled with water, the processor is too heavy to lift and very hard to drain, but fitting a piece of plumbing makes this as easy as removing a sealed cap.

A brand-new unit is quite expensive, but used units can be found readily for sale on internet auctions. These processors control temperature and agitation with sufficient precision to reliably develop all monochrome emulsions, as well as C41 and E6 films. The horizontal tank design, combined with rotational processing, maximizes the film capacity for a given volume of developer. Since less than half the film is submerged in chemistry at any one time, at least twice as many films can be processed with the same amount of chemicals, in comparison to the manual hand-inversion technique. Different-sized drums and film holders are available to process 1 to 12 films in sizes of up to 4x5-inches or larger.

One disadvantage of this processor design is the increased weight of the tank when filled with water. In this state, the processor is rather heavy, and dumping the water, in order to empty the tank, can be difficult and a strain on weak backs. Fig.1b shows an effective homemade adaptation for which a hole was drilled into the tank at the bottom of a side wall. This allows a simple piece of plumbing to be fitted, and draining the tub is now as easy as removing a sealed cap.

### Print Processor

A large darkroom may have plenty of space for a big sink and multiple processing trays for full-size 16x20-inch prints. However, the confinement of a smaller darkroom necessitates the use of a vertical slot processor to make processing of full-size prints possible within a small footprint.

Print processors are available in different sizes and with various numbers of slots, surrounded by a heated or unheated water jacket. One example is the Nova Quad processor (fig.2), which is manufactured by Nova Darkroom in the UK. It is a temperature controlled 16x20-inch unit with four slots to separate developer, stop bath, and a first and second fixing bath. Each slot holds about 3.5 liters of chemical solution, and the prints are held in suspension by special plastic clips, not unlike film hanging clips.

The compact convenience of vertical slot processors is hard to beat. Once filled with fresh chemistry, they are ready for immediate use and require no cleaning until these chemicals are exhausted. During that time, they are always immediately available for print processing. No need to pour chemical solutions in and out of trays or to clean up after each printing session.

Other advantages of this processor design are reduced chemical oxidation and limited output of chemical odor, all due to a relatively small liquid surface area on top of each slot, compared to large open trays.

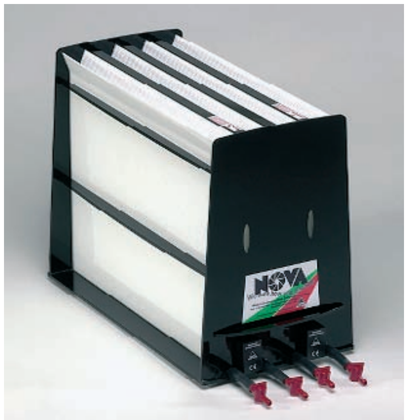


fig.2 The Nova Quad is a temperature controlled 16x20-inch print processor with four slots for developer, stop bath and two fixing baths.

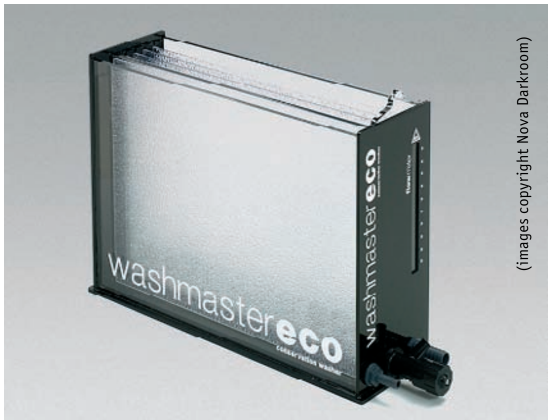


fig.3 Vertical print washers, such as this 16x20-inch Nova WashmasterEco, are the most convenient and compact way to wash multiple fiber-base prints to archival standards with a minimum amount of water.

(images copyright Nova Darkroom)

### Print Washer

No special equipment is required to wash fiber-base prints to archival standards. To wash a single print, all it takes is a simple processing tray, a water hose or a tray siphon, and plenty of fresh water. However, this inexpensive method is rather impractical if multiple prints need to be washed. A far more efficient way to wash a number of prints at the same time is to use a vertical print washer. They are available for different print sizes and typically feature several segregated compartments, each holding one print. At an appropriate flow rate, they provide an effective method of print washing by using a minimum amount of water. This is made possible by an ingenious water replenishment system of jets and weirs. They are the most convenient and compact way to wash multiple fiber-base prints to archival standards.

In the Nova WashmasterEco (fig.3), water is fed into the bottom of each chamber through a small jet and circulates, before falling over an internal weir into the exit pipe. This particular model features a fast drain facility, which allows contaminated wash water to be quickly replaced and has a single slot at one end to hold a hypo-clearing bath. There are similar models available for washing film, but we find it easier to just stick a hose into the development tank and dump the water a couple of times during the wash.

### Water Flow and Temperature Control

Monochrome processes are not as sensitive to temperature fluctuations as their color counterparts. Even so, monochrome process uniformity is made considerably easier if a consistent source of temperature-controlled water is at hand. This is especially true for film development, but it also applies during an unattended wash of film and fiber-base papers. In a domestic environment, it can be quite a challenge to maintain constant water temperature by simply manipulating a set of manual hot and cold valves in the darkroom. Anytime hot or cold water is used elsewhere in the house, the water temperature in the darkroom quickly jumps up or down and requires an adjustment of the valves to avoid emulsion damage or incomplete washing.

One solution is to invest in an electronic temperature control valve, which automatically mixes hot and cold water to achieve the desired temperature and adjusts the mixing ratio up to 50 times a second to ensure a consistent output of water. The Hass Intellifaucet (fig4) is an example of such a unit. It requires little maintenance and provides a much more relaxed working environment by taking an annoying but important task off our shoulders. For example, it responds quickly enough that a toilet flushing anywhere in the house will not be noticed in the darkroom. Without this type of temperature control, temperature spikes of ±20°C are not uncommon.

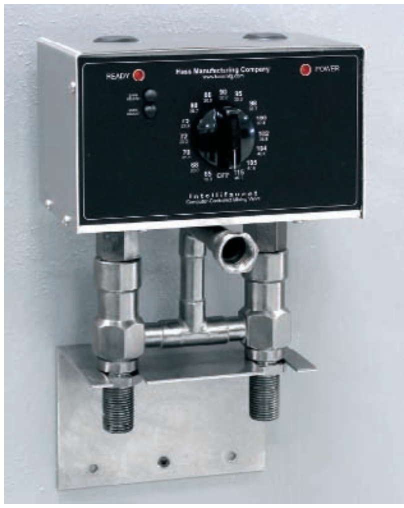


fig.4 The Hass Intellifaucet mixes hot and cold water to produce a constant-temperature water supply. It saves considerable time over trying to manually compensate for seasonal or domestic changes to the water temperature.

(image copyright Hass Manufacturing Company)

### Densitometer

A densitometer is an invaluable tool to objectively measure negative transmission and print reflection densities. Transmission and reflection densities can be measured in absolute or relative values, and it does not really matter which method is used, so long as all comparative readings are taken in the same manner. For relative print and negative density readings, the meter is zeroed on the clear negative or white print border. Absolute negative densities need the meter to be zeroed without a negative in the transmission path, although print reflection densities require that the meter is adjusted to a standard value with the

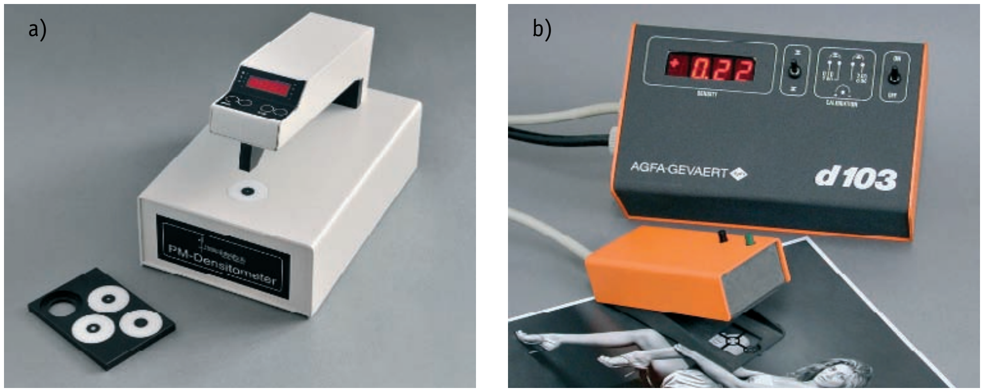


fig.5 A densitometer is an invaluable tool to objectively measure print reflection and negative transmission densities. The Heiland densitometer (a) has a built-in light source, whereas the older unit from Agfa (b) depends on an external light source, such as a light table, to measure transmission densities. The Agfa densitometer can read negatives and prints up to any size, and Heiland offers a model with removable head for the same purpose, plus alternatively sized apertures for different negative formats.

aid of a reflection test target. Throughout this book, relative transmission and absolute reflection densities are simply referred to as transmission and reflection densities. Wherever absolute transmission or relative reflection density values are used instead, they are fully spelled out as such.

Densitometers are not absolutely necessary to make fine prints, but accurately calibrating film, paper and darkroom processes is difficult without them. Furthermore, densitometers can bring consistency to print making. After a long printing session, body and mind get tired and subjective print evaluation eventually fails. At that point, personal print requirements quickly change from looking 'great' to looking 'good enough'. One way to maintain constant print quality is to measure print shadow and highlight densities with a densitometer during printing, on quickly dried samples, and compare them to a predetermined personal standard. This takes a bit more time at first, but it improves print quality, increases self-confidence and avoids sobering disappointments during next morning's fresh-eye review.

Fig.5a shows a modern densitometer, made by Heiland Electronics in Germany, and fig.5b shows an older model, made by Agfa. Both can measure reflection and transmission densities, for which the Heiland has a built-in light source, whereas the Agfa depends on an external light source, such as a light table, to measure transmission densities. The Agfa densitometer can read negatives and prints up to any size, and Heiland offers a model with removable head for the same purpose, plus alternatively sized apertures for different negative formats.

## Darkroom Timers and Meters

This section is predominantly an introduction of RH Designs timers and meters. The reason for that is that we own and use most of their products, many of which Chris designed, patented or wrote software for. Nevertheless, if we thought there were better products out there, we would recommend them. Taking into account that the sophistication of RH Designs products does not necessarily match everyone's requirement and budget, we have added some alternative products, which we have used successfully in the past.

### Process Timer

At the simplest level, anything counting time can be used as process timer. A regular clock or watch will do the job if nothing else is available. Ansel Adams frequently used a metronome as a process timer for his dodging and burning efforts. However, in order to achieve reasonable process consistency and to eliminate human error as much as possible, every darkroom needs a dedicated process timer.

In the US, the GraLab 300 series of timers have been popular models for decades (fig.6a). They come with plain or self-illuminated face plates, which are easily seen in the dark. They are simple and reliable backwards-counting process timers, also capable to turn enlarger, safelights or other darkroom equipment on and off as needed.

The RH ProcessMaster II is a more sophisticated process timer, able to store multiple sequences of processing steps (fig.6b). It can apply factorial development and other automatic process adjustments to ensure consistency in film and paper development by compensating for fluctuating temperatures and ageing developers. This process timer can count down in seconds or in percent with an optional pause between process steps.

### Enlarger Timer

We have purposely avoided introducing ordinary linear enlarger timers in this chapter, because we have both been using f/stop enlarger timers for years and cannot recommend using any other timing concept. Although f/stop timers do not make a better print, it is hard to go back to an ordinary timer once you have used one. These timers change exposure in multiples of 1/12 stop and have, depending on the model, additional features that compensate for paper reciprocity, dry-down, as well as lamp delay and warm-up effects. This eases mental and physical efforts during the printing process. Once a print is made, at any exposure time, it is a simple matter to provide an extra burn-in exposure, measured in f/stops, with a few button presses. Automatic test strip exposure sequences are also generated in f/stops, using coarse or fine steps, which permits the user to determine a burn-in or fine-tuning exposure that is recorded and effortlessly reproduced at any enlargement size.

RH Designs introduced two f/stop timers to control the enlarger and optionally the safelights, first the StopClock LE (fig.7a) and later the current StopClock Pro (fig.7b). Each is able to apply exposure increments in fractions of an f/stop and calculate test strip sequences. The current model, on the right, has a number of additional features including stored exposure sequences for complex printing.

### Enlarger Meter

The most accurate method to determine optimal print exposure and contrast is to prepare test strips for both. Actually looking at exposure increments, ranging from too light to too dark, is the only way to confidently select the optimum exposure time. Similar is true for selecting print contrast. However, a good and well-calibrated enlarger meter can propose near-optimum values, based on a few simple measurements. The meter utilizes the projected brightness of an image-representative shadow and highlight area to calculate print exposure and global contrast. This produces a well-exposed work print with good overall contrast in the shortest time possible. This initial work print is the foundation for any additional fine-tuning efforts, which are more effectively conducted using the proven test-strip method above. The combination of modern technology and proven technique provides the best result in the shortest amount of time.

The Ilford EM10 (see fig.8a) is a good, entry-level, low-budget meter. As with all other enlarger meters, it must be calibrated for each paper first, but afterwards, it predicts optimum exposure times with ease and reasonable accuracy. This timer cannot be beat when it comes to value for money. However, we prefer enlarger meters with f/stop-timing capability. Figures 8b&c show the ZoneMaster II and the Analyser Pro from RH Designs. Both meters use a remote spotmeter to measure several points on the projected negative and reference them against the meter's built-in grayscale. This patented grayscale display allows the user to convert any desirable print tone into a particular paper exposure and contrast setting. The outcome is a quickly made but accurate work print, which serves as a sound foundation for fine-tuning further prints or as an excellent product for less critical applications.

The ZoneMaster II is a separate meter, and consequently, the exposure information must be passed over to an enlarger timer. This can be done manually, or this stand-alone unit can be connected to any StopClock via a cable. The Analyser Pro combines the meter function with an f/stop timer into one unit and

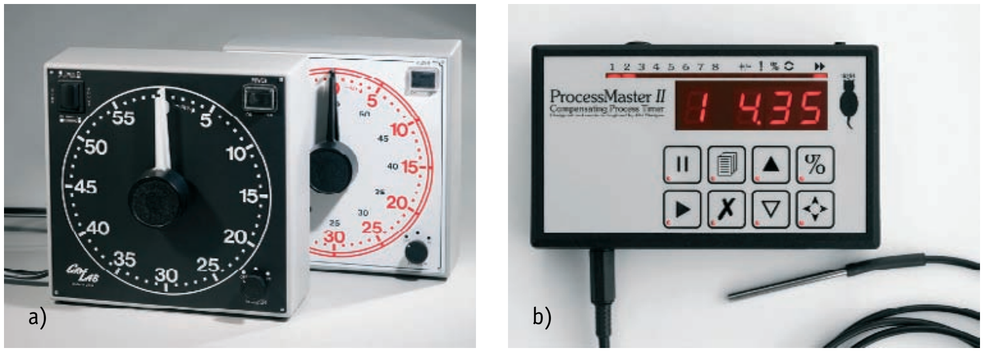


fig.6 The GraLab 300 series of timers (a) come with plain or self-illuminated face plates to easily see them in the dark. They are simple and reliable backwards-counting process timers. The RH ProcessMaster II (b) is a more sophisticated process timer. It is able to store multiple sequences of processing steps and compensates for fluctuating temperatures and ageing developers.

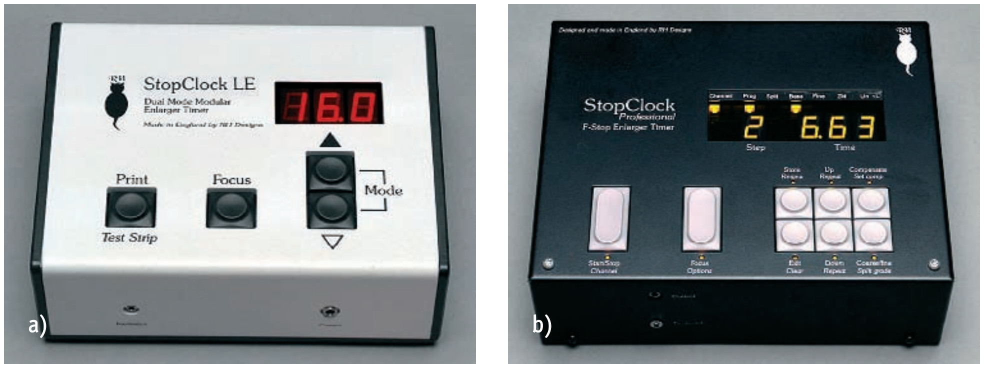


fig.7 It is hard to go back to a linear timer once you have used an f/stop timer. RH Designs first introduced the StopClock LE (a), and later the StopClock Pro (b), to control the enlarger and, optionally, the safelights. Each is able to apply exposure increments in fractions of an f/stop and calculate test strip sequences. The current model has a number of additional features including stored exposure sequences for complex printing.

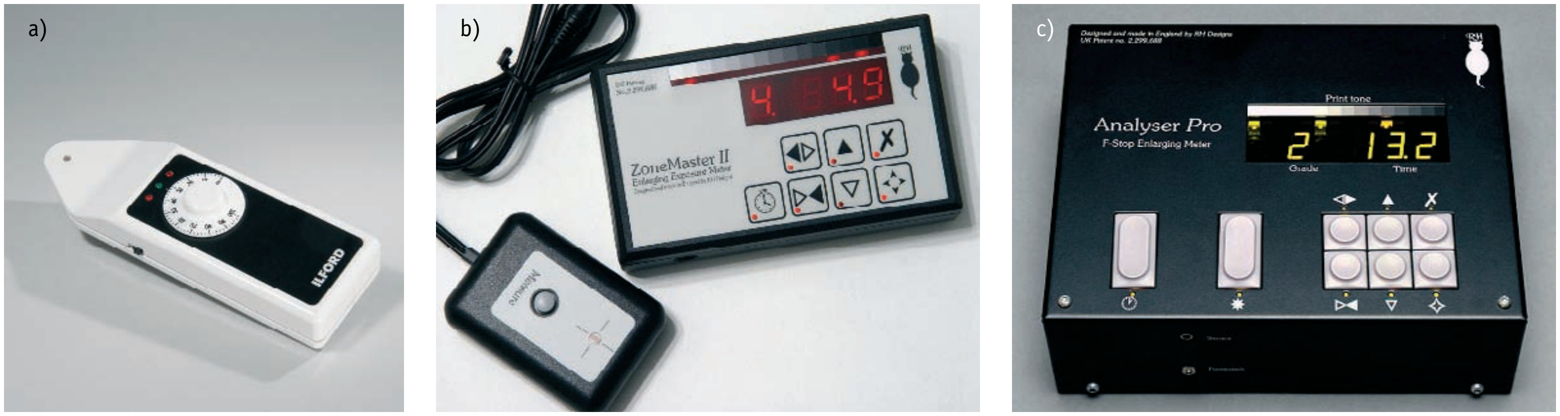


fig.8 A well-calibrated enlarger meter can propose near-optimum values, based on a few simple measurements. The Ilford EM10 (a) is a good low-budget meter and cannot be beat when it comes to value for money. However, we prefer the more sophisticated ZoneMaster II (b) and the Analyser Pro (c) from RH Designs with their f/stop timing capability.

controls enlarger timing directly. These meters save time and material, as they help to quickly interpret a new negative. They also function as basic densitometers, by reading relative light levels when a negative is projected on the baseboard or easel.

## Negative Focus and Paper Support

### Focus Finder

It is impossible to achieve maximum print sharpness without an accurately focused projection of the negative on the baseboard. With some experience, easily recognizable image features and good eyes, this is a manageable task at reasonable magnification levels, and the depth of field around the paper plane provides a certain focus tolerance anyway. Nevertheless, many darkroom workers prefer the increased precision and confidence provided by a focus finder.

A focus finder is an optical aid to examine the virtual image, projected by the enlarger, in order to ensure that the negative image is accurately focused on the printing paper. Focus finders are designed so that the length of their optical path is exactly equal to the length of the optical path that they interrupt. This is achieved by using an angled mirror and a magnifying eyepiece to examine the reflected virtual image. The enlarger lens is carefully focused until highly magnified image detail, or the grain structure of the film, can be seen in focus.

Typical focus finders magnify the projected image 10-25 times, which, multiplied with the scale of the enlargement, is comparable to microscopic magnification levels. This explains why focus finders are also referred to as grain focus finders. The quality of a focus finder depends on its dimensional stability. We, consequently, discourage the use of inexpensive plastic models.

The MicroSight, made by Bestwell Optical, is a low-budget, 25x grain focus finder, featuring an adjustable eyepiece and a sturdy metal construction (fig.9a). It is a fully reliable focus finder and used for the majority of our focusing needs. The Peak 2000 (Model I) is a high-quality focus finder, featuring 10x magnification, an aluminum die-cast body and precision optics (fig.9b). The major benefit of this popular focus finder is that it not only finds perfect image

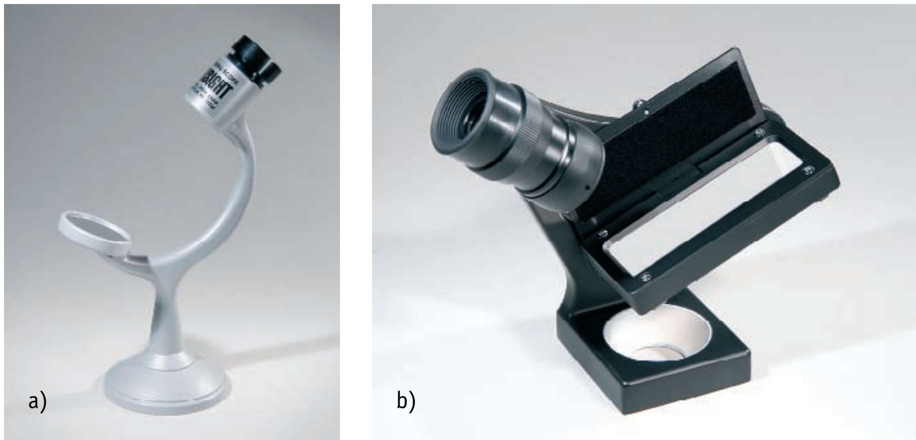


fig.9 A focus finder is an optical aid to ensure that the negative image is accurately focused on the printing paper. The MicroSight (a) is a reliable focus finder with sturdy metal construction. The Peak 2000 (b) features 10x magnification, an aluminum die-cast body and its unique design allows edge-to-edge focus checking.

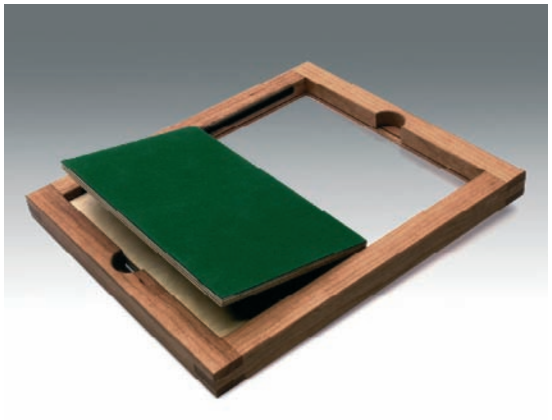


fig.10 A printing frame is an essential accessory for contact-printing to keep the negative and print in perfect contact over their entire surface when printing digital negatives. The solid cherry-wood frame, made by Lotus View Camera, features a felted hinged back. Two strong springs lock into runners along the frame and clamp the print securely to the negative over the entire surface.

(image copyright Lotus View Camera)

focus at the picture center but also at any position within the image area, allowing edge-to-edge focus checking. However, it is not a true grain focus finder, due to its limited magnification.

A common recommendation is to use a piece of paper underneath the focus finder, simulating the missing thickness of the printing paper, for increased accuracy. This is theoretically a sound approach, but in practice, a paper-thin focusing error is just too small to create a detectable out-of-focus condition. On the other hand, if you are working with a black easel, and therefore need a piece of white focusing paper anyway, you are already focusing on the correct, theoretically perfect, image plane.

### Contact-Printing Frame

Enlarging a negative inevitably reduces image quality. This effect is minimized by using the largest negative possible. Nevertheless, ultimate image quality is only achieved if enlarging is avoided altogether, and the negative is brought into direct contact with the printing paper and firmly held in place during the exposure. Contact printing produces a print the same size as the negative.

For occasional contact printing, firm contact between negative and paper can be accomplished by weighing down both with a heavy glass plate. But, a dedicated printing frame is an essential accessory for more frequent contact-printing needs. The frame keeps the negative and print in perfect contact over their entire surface when printing digital negatives or when using so-called ‘alternative processes’.

Traditional printing frames are deceptively simple to make, and some darkroom workers will choose to make their own. Alternatively, sturdy frames, crafted from hardwood, are still available from a few specialists. The frame shown in fig.10 is manufactured by Lotus View Camera in Austria. It has a solid cherry-wood frame for strength and features a felted hinged back to support printing by inspection. Two strong springs lock into runners along the inner sides of the frame and clamp the print securely to the negative over the entire surface.

### Enlarger Easel

At its simplest level, an enlarging easel holds the paper flat and allows accurate positioning. Several master printers get away with using nothing but a thick wooden board and a few pieces of double-sided tape to hold the paper in place. More elaborate easel designs offer leveling feet, alignment grids, adjustable masking and pen lining.

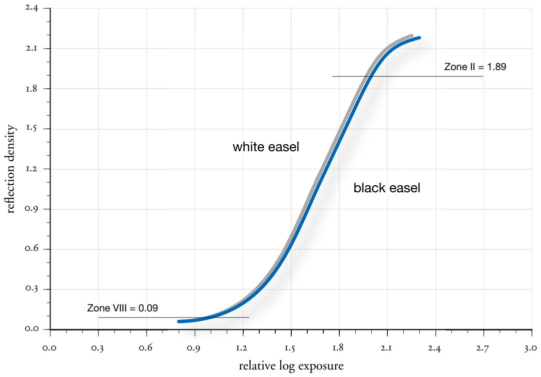


fig.11a The color of the easel surface is of some practical importance. During the exposure, some light is transmitted through the paper, reflected by the easel and added as unwanted exposure from the back. This has an effect on print exposure and contrast.

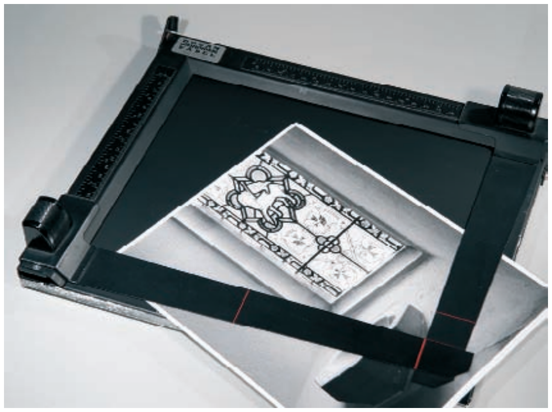


fig.11b A black easel eliminates unwanted print fogging and avoids telltale signs of printing records, written on the back of the paper prior to the exposure.

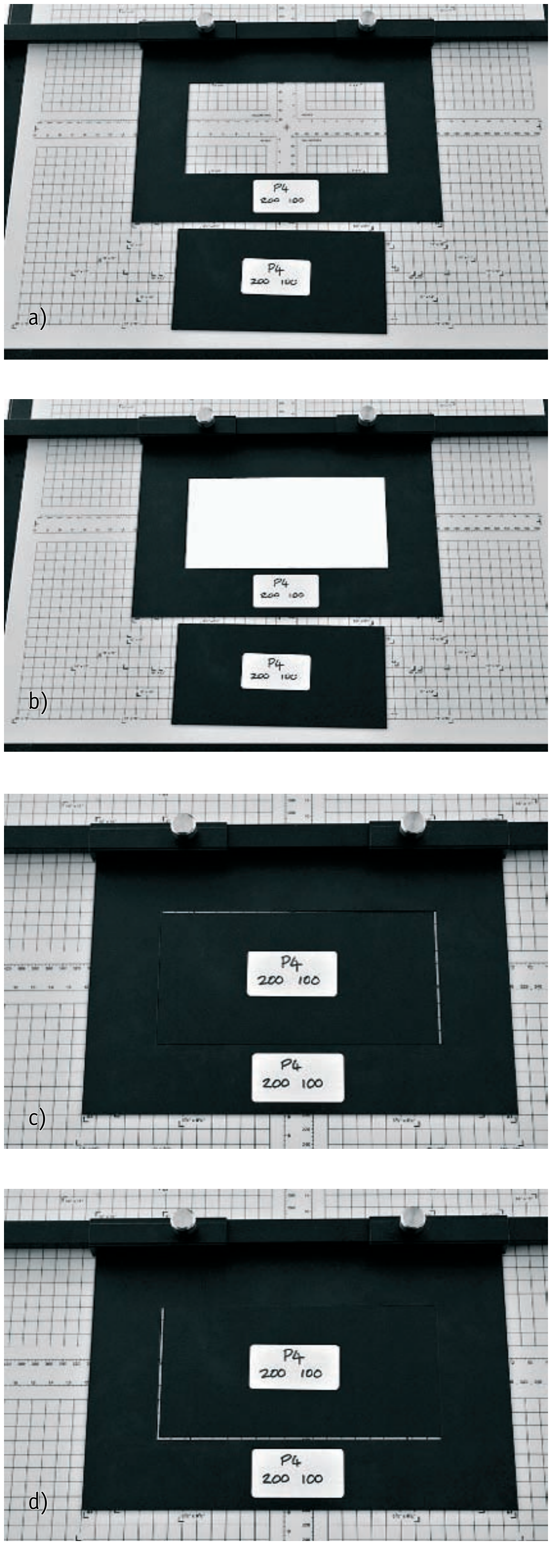


fig.12 With a few simple steps, you can add a precision pen line to your print. What you need is a steel baseboard with a radiating grid to center the prints, a set of standard-size print masks with slightly undersized inserts, both cut from opaque plastic, and a couple of magnets. In (a), the plastic mask is centered on the grid, and the enlarger is set up for this enlargement size. In (b), the paper is slid under the mask, and a few magnets are used to secure mask and paper. After the final print exposure has been made, the undersized insert is placed into the aperture of the mask and pushed into the lower left-hand corner (c). At this point, a flash light is used to burn in half of the pen line. This is repeated with the insert in the upper right-hand corner to finish the pen line (d). Ralph does not like the constraint of standard enlargement sizes, but Chris prefers consistency between images likely to be shown together. Not every print requires a fine pen line around the image, but especially with high-key images and images with distracting but image-relevant features close to the image border, pen lines provide a visual framing effect and 'hold' the image together.

The color of the easel surface is of some practical importance. Photographic paper is not completely opaque. Typical double-weight paper transmits between 6-12% of the light it receives. A bright-white easel reflects 80-90% of that back into the paper and adds unwanted exposure from the back. On average, this is similar to 1/12 stop fogging exposure. Fig.11a illustrates the effect on print exposure and contrast. On a white easel, print shadows and midtones receive appreciably more exposure, compared to a black easel, which raises the print contrast slightly. In practice, this is of little concern, unless differently colored easels are used during the printing session. However, if one has developed the habit of recording exposure and contrast data on the back of the paper, and does so prior to the print exposure, tell-tale signs of these records may be noticeable in uniform midtone regions.

Ralph prefers a plain black easel for its simplicity (see fig.11b). Chris uses a steel-based pen-lining easel and pre-cut plastic masks and inserts (fig.12). After the final print exposure, the undersized insert is placed in opposite corners of the mask's aperture, which allows a fogging exposure to create a perfect thin black pen line (fig.13). The image sequence in fig.12 shows the principle and the equipment required. It will enable practical photographers to make their own. The alignment grid is a great help when centering prints and checking verticals in the image.

## Other Printing Tools

### Paper Flasher

Flashing and fogging prints can be accomplished in a number of ways. They require a low-level, controllable and uniform light beam over the enlarger easel. Some darkroom workers dedicate an old enlarger for the purpose, while others use a diffuser, in the form of a polystyrene cup, over the enlarger lens.

The RH Designs PaperFlasher II (fig.14) is a sophisticated way to flash and fog prints. It combines an f/stop timer with a low-level, diffused light source, which can be positioned centrally or locally over the easel. Its built in test-strip mode enables one to precisely select the correct exposure level. The light unit has a removable outer diffuser, which, when removed, increases the light level for print fogging or burning in pen lines. The two light levels are fixed for convenient consistency and accuracy.

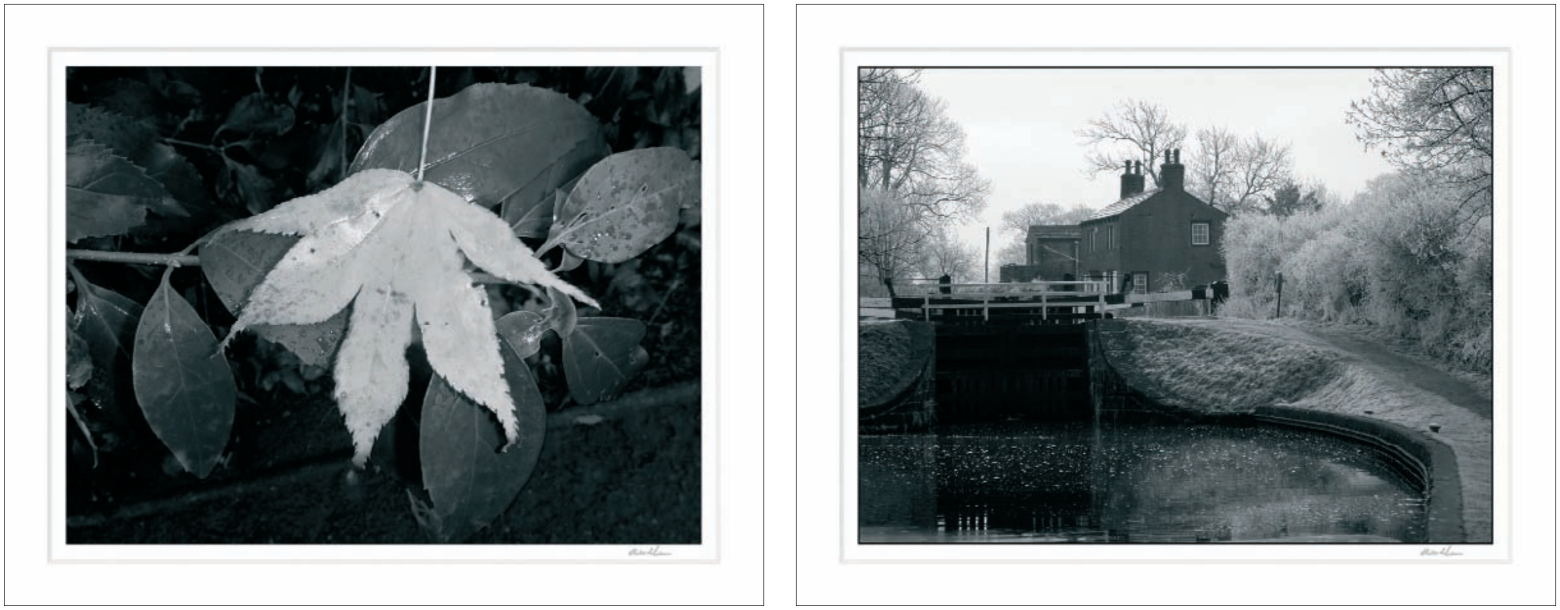


fig.13 A pen line is a thin, black line, marking the image periphery. It is added during or after darkroom exposure and helps to frame the image, keeping the picture together as one unit and preventing the viewer's eye from drifting off the image into the border. Some images benefit from a pen line more than others. The image on the left is sufficiently self-contained to work without it, but the blank sky in the image on the right clearly benefits from the added pen line.

(images by B. Woodhouse)

### Darkroom Torch

Every now and again, you need an additional small light source in the darkroom. It should be portable and sufficiently safe, so that brief exposures do not fog film or paper, but it must be bright enough to accomplish all the special tasks for which regular safelights are too bright or only provide insufficient illumination. Imagine the following examples: After inserting the film into the reel and placing it into the development tank, you accidentally drop the lid. It can be a challenge to find the lid in the dark, during which time the film is left unprotected. Or, you might be in the middle of a complex printing sequence when you start looking for that special, custom-made dodging tool, only to realize that it still must be in one of those boxes under the sink.

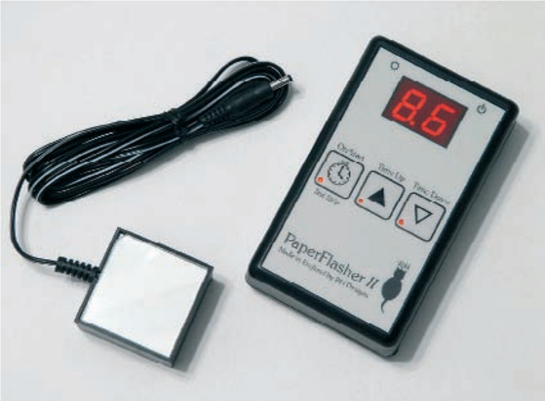


fig.14 The PaperFlasher II is a sophisticated way to replace a polystyrene cup for flashing and fogging prints. It combines an f/stop timer with a low-level diffuse light source and includes a built-in test-strip mode.

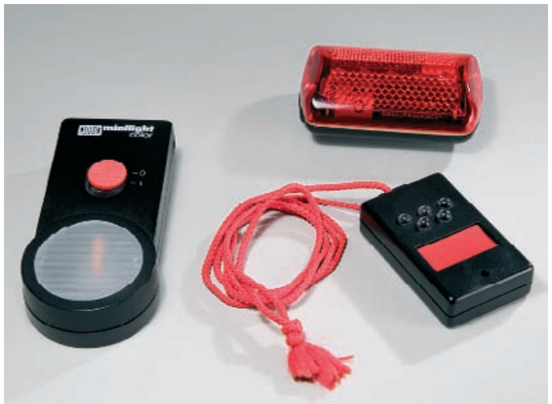


fig.15 Every now and again, you need a darkroom torch. Modern LED technology makes it possible to limit their light output to a narrow wavelength, outside the sensitivity range of film and paper.

A darkroom torch is the perfect tool on these occasions, because turning on the lights is not a viable option. Several models are shown in fig.15, and modern LED technology makes it possible to limit their light output to a narrow wavelength outside the sensitivity range of film and paper. They are all handheld, battery-operated devices. The Ilford model (left) is designed for color and monochrome papers, the RH Designs model (bottom right) features a push button and is safe with most monochrome materials, and the bicycle tail light (top right) was successfully diverted from its intended use.

### Pin-Registration and Masking Kit

Accurate pin registration is essential for any of the precision masking techniques described in this book. It is possible to line up a 4x5-inch negative and mask, by eye under a loupe, and secure the sandwich with a piece of tape, but with any smaller format, human tolerances take hold and a mechanical aid to accurately align the two is required. In today's market, however, the choices are very limited. The Precision Pin-Registration Carrier System from Lynn Radeka Photography is designed for making prints with unsharp or contrast controlling masks (fig.16). It fits most enlargers and is composed of a machined aluminum frame, which fits snugly in the enlarger's negative stage. The frame acts as a receptacle for the accompanying pin-registration glass carrier, which slides into the frame and comes to a positive, perfectly registered stop without any lock knobs or latches. In addition to making and printing with masks, it can also be used for double-printing techniques, and it is sufficiently precise to allow printing with separation negatives.

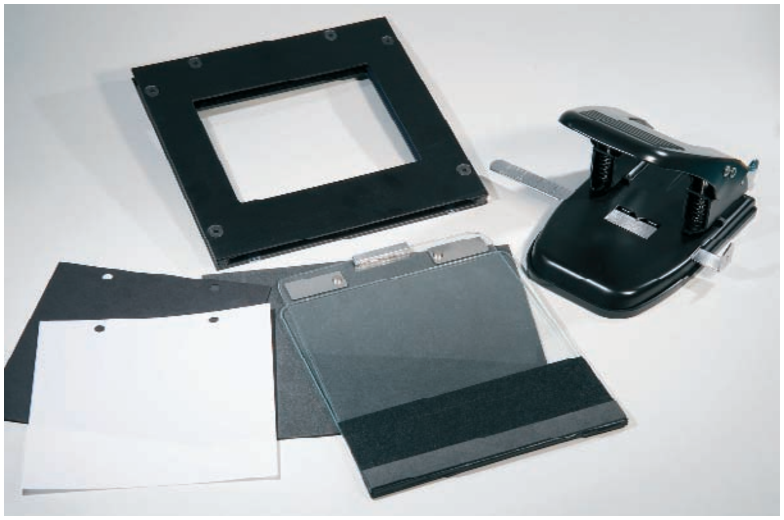


fig.16 The Precision Pin-Registration Carrier System from Lynn Radeka Photography is designed for making and printing with unsharp or contrast controlling masks, and it can also be used for creative double-printing techniques.

## Review Questions

1. Which of the following statements is true?
    a. the effective speed of a leaf shutter changes with aperture setting
    b. a tripod makes no difference with shutter speeds below 1/f s
    c. darkroom walls should be painted flat black
    d. all photographic papers require the same safelight filter

2. How do condenser and diffusion enlargers affect print quality?
    a. print sharpness is independent of enlarger type
    b. diffusion enlargers create smoother highlights
    c. condenser enlargers are sharper but highlight dirt and dust
    d. condenser enlargers block up shadow detail

3. How can print sharpness be optimized?
    a. by using a glass-less negative carrier
    b. by avoiding below-the-lens filters
    c. by keeping exposure times below 10 s
    d. by using a perfectly aligned wall-mounted enlarger

4. How do you get the best performance from an enlarging lens?
    a. nothing to worry about, all enlarging lenses are good
    b. by using its optimum aperture
    c. by stopping it all the way down
    d. by only buying name brand lenses

5. What else can be done to significantly improve print sharpness?
    a. use a vacuum easel to keep the paper as flat as possible
    b. use the Scheimpflug principle when correcting for converging lines
    c. place a piece of paper under the focusing aid
    d. use the smallest aperture possible to extend the depth of field

6. Which of the following statements is true?
    a. f/stop timing does require an f/stop timer
    b. archival washers are more effective than tray washing
    c. a good enlarger meter eliminates the need for test strips
    d. the color of the enlarger easel can negatively affect print quality

7. How does a pen line affect print quality?
    a. should be added consistently
    b. should not be added, because it negatively affects print longevity
    c. it frames the image and keeps the pictures together as a unit
    d. only useful for unframed prints

1a, 2c, 3d, 4b, 5b, 6d, 7c

© 1997 by Ralph W. Lambrecht, all rights reserved

# Tools, Tips and Tricks

This page intentionally left blank

# Identification System for Film Holders

## A binary numbering pattern for large format sheet film

Today's roll films, both 35mm and medium format, are marked with the manufacturer's name, the product name, and the frame numbers. The pre-exposed frame numbers don't always perfectly match the frames we are exposing, but they still allow us to correlate our exposure records with each individual frame on the roll. This is a service too easily taken for granted, and the benefits of it did not become apparent to me, until I exposed and developed my first sheet film.

Sheet film, in sizes 4x5 inches and up, does not have any pre-exposed markings on it. The only standard identification is a pre-cut notch system, which specifies the manufacturer and the product itself. This system identifies the film in front of you, as Kodak's TMax-400 for example, and another negative as Ilford's FP4, but it does not tell you which of your film holders was used during the exposure of a particular negative. However, this is valuable information to a careful photographer, for a couple of reasons.

Not all film holders function with exactly the same results. Their purpose is to hold the sheet film flat at the image plane, within a given tolerance, and to provide a light tight environment, protecting the film while closed. When they get older and begin to wear, they may lose one or both functions and the possible results are unsharp images and light leaks. It would be useful to know, by looking at the ruined negative, which holder failed, so that the culprit can be eliminated or repaired. Luckily, I have never had such a drastic failure, but since I began numbering my film holders, I have discovered that some produce a sharper image than others. A far stronger reason to correlate film holders with individual negatives are the detailed exposure records I keep.

I am in the habit of making precise exposure records. During every photo session I record the shutter speed, aperture, focal length, filtration, reciprocity modifications, subject brightness range, and any other relevant data for every frame or film holder number used. I like to have this data, because it allows me to learn and improve, and it can be interesting reference information in the future. The tedium of recording this data can be a chore, but it is made easier using a simple handheld tape recorder. The data is recorded within seconds and is available for later transcription to my written records, which are then filed with my negatives.

Unfortunately, a limited number of film holders and sorting sheet film by development needs can lead to a loss of the correlation between a particular negative and the related sheet film holder. Here is an example. I own 12 holders allowing for 24 exposures, which is enough for my shooting habits to last me for a

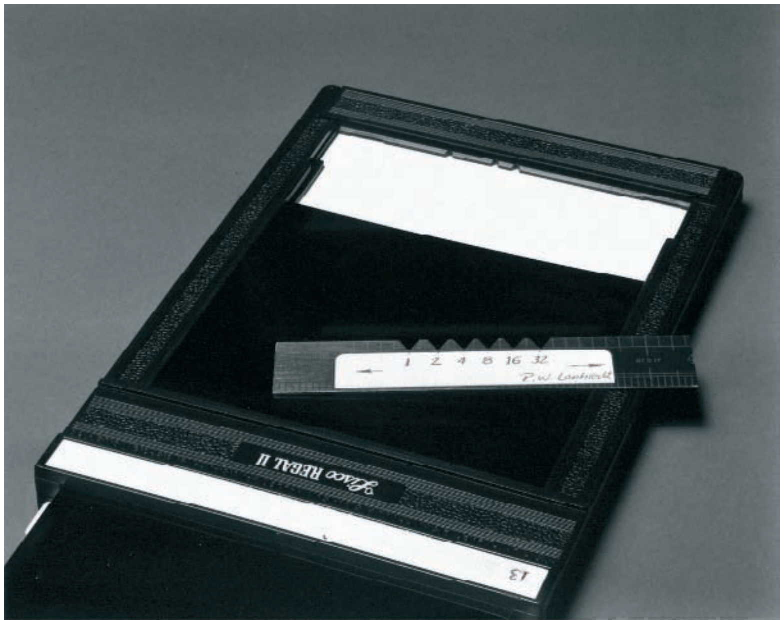


fig.1 With the use of a steel template, a binary notching system can be cut into the bottom lip of the film holder. This correlates the sheet film with the holder after development.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50074-0

fig.2 The decimal system

| decimal base & exponent | $10^3$ | $10^2$ | $10^1$ | $10^0$ |
|---|---|---|---|---|
| decimal | 1,000 | 100 | 10 | 1 |
| 13 | 0 | 0 | **1** | **3** |
| 21 | 0 | 0 | **2** | **1** |

fig.3 The binary system

| binary base & exponent | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|---|
| decimal | 32 | 16 | 8 | 4 | 2 | 1 |
| 13 | 0 | 0 | **1** | **1** | 0 | **1** |
| 21 | 0 | **1** | 0 | **1** | 0 | **1** |

day. At the end of the day, the film holders are emptied and the exposed film sheets are stored in separate old film boxes, depending on the suggested development compensations, from N-3 to N+3. At this point, the holders are loaded with fresh film, so they are ready for the next day. After the film is developed, one box at a time, a correlation between the film holders and the exposure records is lost or difficult to retrieve. A precise subject and image description on the audiotape can help, but often fails when multiple exposures of the same scene were taken.

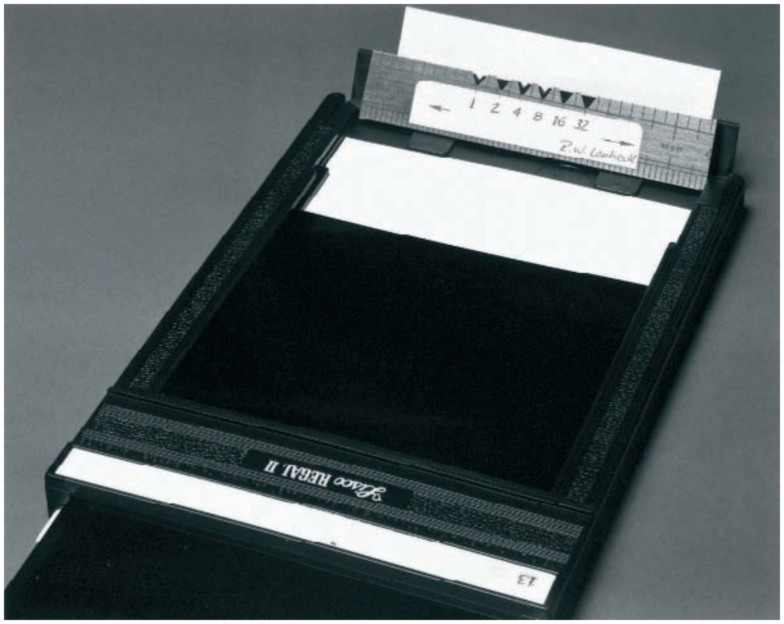


fig.4 The template in cutting position. The numbering is reversed, because the films emulsion is pointing up while in the film holder.

I have solved this problem by notching all of my film holders with a binary pattern. It leaves a permanent mark on the negative, clearly identifying the film holder used, without any intrusion into the image area. Fig.6 shows a negative and the binary pattern left from film holder number '21'.

## The Binary System

To understand this system, you only need to understand general numbering systems, and the binary system is actually the simplest of them all. Let's first look at the familiar decimal system. Fig.2 shows the basics of the system with two examples. From right to left, each digit is dedicated to the base of '10' with increasing exponent values, each of which can hold any number from 0-9. Therefore, we have a digit for the singles, the tens, the hundreds and so on. To display the number '13' in the decimal system, the digit for tens is set to '1' and the singles are set to '3', summing up to the desired '13'. We were all brought up with the decimal system, and it is second nature to us. We assume the base of '10', when communicating numbers, to the point that we forget about it altogether. The binary system is very similar to the decimal system. The only difference is that it assumes a base of '2' and not '10'. Therefore, each digit can only hold numbers from 0-1. Consequently, we now have digits for singles, twos, fours, eights, sixteens and so on. Fig.3 shows the basics of the binary system using the same two examples as before. To display the number '13' in the binary system, the digits for eights, fours and singles are set to '1' and the sum will make the desired '13'.

The benefit to our application is that each digit of a binary number can only hold a number from 0-1, whereas in the decimal system, it can be any one of ten numerals. A simple notching system can simulate one of two conditions easily, by either having a notch at a certain location or leaving the location without a notch.

## Cutting the Holders

I am only familiar with the film holders from Lisco, Riteway and Fidelity. They all have a lower lip, which is taped to the holder, to form a hinge. Fig.4 shows this lip lifted up, as it would be to insert or remove sheet film. This lip also holds the film down, when the holder is closed.

The lower part of the lip is an ideal location to place the binary notches. The lip has a groove for the dark slide to fit into, and we want to make sure that only the side in contact with the film receives the notches. This prevents the use of a file, which would cut into the upper lip as well. A file would also create unwanted dust particles, which may be hard to remove. The best way to cut the notches is with the tip of a sharp utility knife, guided by a customized steel template.

Get a small steel ruler from the hardware store and cut it to length, so it fits inside of the holder. Then, using a small triangular file, create six notches, 1/8 inch deep and 1/4 inch apart from one another. Fig.4 shows the template with a sticker to mark the binary values of each notch. The numbering sequence is reversed from the table in fig.3, because we are looking at the underside of the lip while cutting the notches and at the film emulsion side when reading them. At this point, insert the template into every holder in question and notch them one by one, being very careful not to cut yourself. A pair of heavy leather gloves will protect your fingers, and a pair of goggles will save your eyes. This template will allow you to mark up to 32 double-sided holders, but if required, an additional notch will double this amount. Getting used to the binary system can be confusing at first, but you will soon get the hang of it. It is the most efficient way to cut a minimum amount of notches. Fig.5 shows where to cut the correct notches for up to 12 double-sided film holders, and fig.6 shows how to use the steel ruler to read the notches on a sample negative.

I haven't had to eliminate any of my film holders due to focus problems or light leaks yet, but correlating my exposure records from the field to the right negative is now a much easier task.

|  | 1 | 2 | 4 | 8 | 16 |
|---|---|---|---|---|---|
| 1 | ▼ |  |  |  |  |
| 2 |  | ▼ |  |  |  |
| 3 | ▼ | ▼ |  |  |  |
| 4 |  |  | ▼ |  |  |
| 5 | ▼ |  | ▼ |  |  |
| 6 |  | ▼ | ▼ |  |  |
| 7 | ▼ | ▼ | ▼ |  |  |
| 8 |  |  |  | ▼ |  |
| 9 | ▼ |  |  | ▼ |  |
| 10 |  | ▼ |  | ▼ |  |
| 11 | ▼ | ▼ |  | ▼ |  |
| 12 |  |  | ▼ | ▼ |  |
| 13 | ▼ |  | ▼ | ▼ |  |
| 14 |  | ▼ | ▼ | ▼ |  |
| 15 | ▼ | ▼ | ▼ | ▼ |  |
| 16 |  |  |  |  | ▼ |
| 17 | ▼ |  |  |  | ▼ |
| 18 |  | ▼ |  |  | ▼ |
| 19 | ▼ | ▼ |  |  | ▼ |
| 20 |  |  | ▼ |  | ▼ |
| 21 | ▼ |  | ▼ |  | ▼ |
| 22 |  | ▼ | ▼ |  | ▼ |
| 23 | ▼ | ▼ | ▼ |  | ▼ |
| 24 |  |  |  | ▼ | ▼ |

fig.5 (top) This notching table shows where to cut the correct notches for up to 12 double-sided film holders.

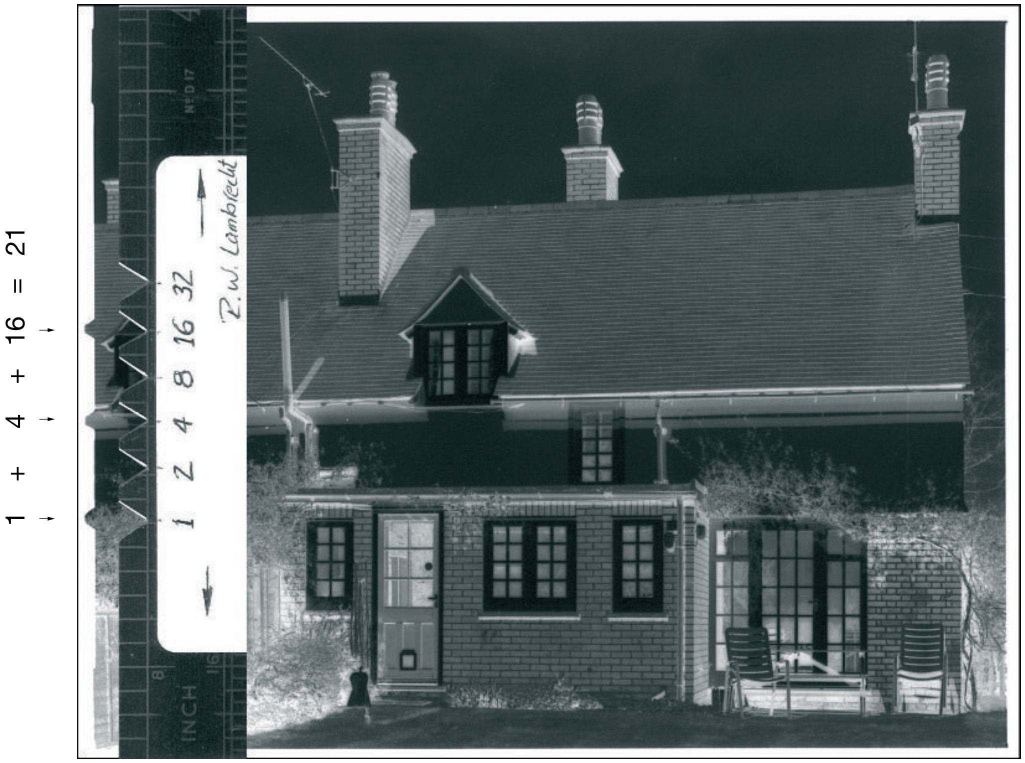


fig.6 The notches in the film holder '21' left a permanent imprint on a sample negative, here shown with the emulsion side up. The same steel ruler, used to cut the notches, can be used after film processing to identify which film holder was used during exposure. This is best done with the negative in its protective sleeve, where the sensitive emulsion side is protected against scratches.

# How to Build and Use the Zone Ruler

## Visualization can be learned, but it takes practice

The ability to visualize a scene, and later accurately expose and develop the negative accordingly, is one of the great benefits of the Zone System. Being able to direct any subject brightness to a desired print zone on the final print gives great confidence and enables the photographer to combine creativity with predictable technical excellence. However, visualization of the final print zone densities takes practice. Many disappointing prints are the result of underestimating how dark Zone VII really is, or realizing the sobering fact that Zone III does not always reveal as much detail as anticipated.

I often ask students of my Zone System classes to identify their preferred print zones for the shadows and highlights of a sample scene. The typical answers for any particular subject area are spread relatively widely over two zones. This is not necessarily a problem, as long as it is due to individual artistic interpretation of the scene. However, the students are in much closer agreement when asked to point out the intended print density on an unmarked step tablet. This indicates that accurate visualization of print densities requires some experience, and a sample step tablet, as in fig.1, can be a valuable training aid.

### How to Make Your Own

With the help of a few paper tests, a densitometer and the density table in 'Tone Reproduction Cycle', you could make an extremely accurate Zone Ruler. However, this level of precision is hardly necessary for a tool intended to aid in the subjective evaluation of subject brightness. Let's look at a much faster approach, which allows you to make your own Zone Ruler with ease and appropriate accuracy.

In the darkroom and armed with a Kodak Gray Card, find the exposure time required to create a density closely matching the card's 'average' gray, using a paper contrast of grade-2. Using fig.2, you can refer to this density as being Zone V and its base exposure time as being 100%. If you are working with variable-contrast

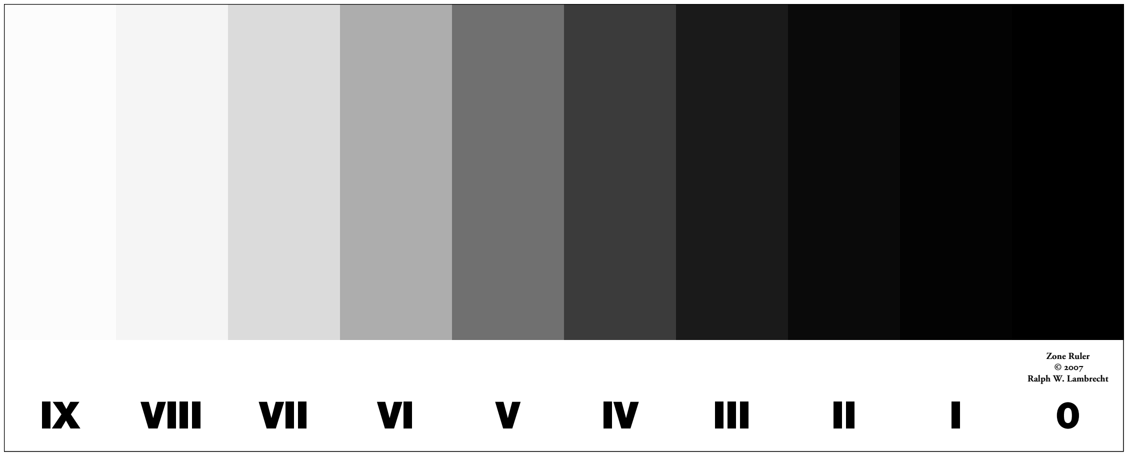


fig.1 The Zone Ruler provides a handy reference to the representation of subject brightness in the final print.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50075-2

papers, and are not certain how to filter for an ISO grade 2, just skip the filtration and use only the 'white light', because the exposure variations in fig.2 are very sensitive to paper contrast.

Now, use an 8x10-inch piece of paper and divide it evenly into ten patches. Leave the first patch (Zone IX) paper white without any exposure. Then, expose each remaining patch for a percentage of Zone V, as indicated in fig.2, by sliding a dodging card step by step from left to right after each exposure. Use the incremental percentages from fig.2 to calculate your actual exposure times from the base exposure time for Zone V. That is, cover the first patch (Zone IX) to keep it paper white, and expose for 25% of the base exposure time to create a patch matching Zone VIII. Then, move the dodging card, and expose for an additional 15% of the base time to create Zone VII, then 20% more for Zone VI and so on. This creates print densities with adequate accuracy. However, verify by checking Zone VIII, which should be just off-white. If necessary, modify to the exposure times (±5%), in order to fine-tune the Zone Ruler to your paper.

Develop and process the print normally and label the zones as shown in fig.1. Cut the print to size and glue it to a piece of mounting board, which gives your Zone Ruler more stiffness and increases its durability. My ruler has found a permanent place in the camera bag. I do not recommend any surface protection for the ruler. It just adds the risk of potential flare and alters the surface appearance to a point where it may not be representative of the final print surface anymore.

## How to Use It

The Zone Ruler is used as a comparative scale. Hold it up at arm's length, as shown in fig.3, to compare the brightness of any portion of the scene with the steps on the ruler. This enables you to distribute the entire subject brightness range over the available print zone densities.

Here are a few tips on how to use the ruler successfully and how to avoid a few pitfalls. Always try to hold the ruler so the light falls on the ruler the same way it falls on the subject area in question. In fig.3, the sun has just lost the right garage door to the shade, and the ruler is held in a very similar position. Finally, avoid light reflections on the ruler, because they may get in the way of a realistic comparison.

Don't allow the Zone Ruler to interfere with your creative visualization process. It is a useful tool, however, to make you aware of the available print zone densities. Use it wherever an accurate and lifelike tonal interpretation is required. Nevertheless, a realistic representation of the subject tonality is not always in the best interest of creative fine-art photography. You, the artist, are still in charge of the image. You decide which subject tones are to be represented as shadow or highlight zones and give the image the appropriate impact. Use the ruler as recommended, but don't let it stifle your creativity.

The Zone Ruler is a quick reference guide to the available print zones. It is a valuable tool to have, and easy to make. Students of the Zone System, who use the ruler, can accurately translate subject tones to realistic print zones with much more consistency than without it. Remember, however, that artful visualization is successfully performed only by the human mind.

| Zone | exposure time [%] | |
|---|---|---|
| | absolute | incremental |
| IX | - | - |
| VIII | 25 | 25 |
| VII | 40 | 15 |
| VI | 60 | 20 |
| V | 100 | 40 |
| IV | 150 | 50 |
| III | 210 | 60 |
| II | 300 | 90 |
| I | 420 | 120 |
| 0 | 600 | 180 |

fig.2 The individual zone patch exposure times are in %, relative to the appropriate time required to create a Zone-V density (100%). This table provides absolute and incremental exposure times.

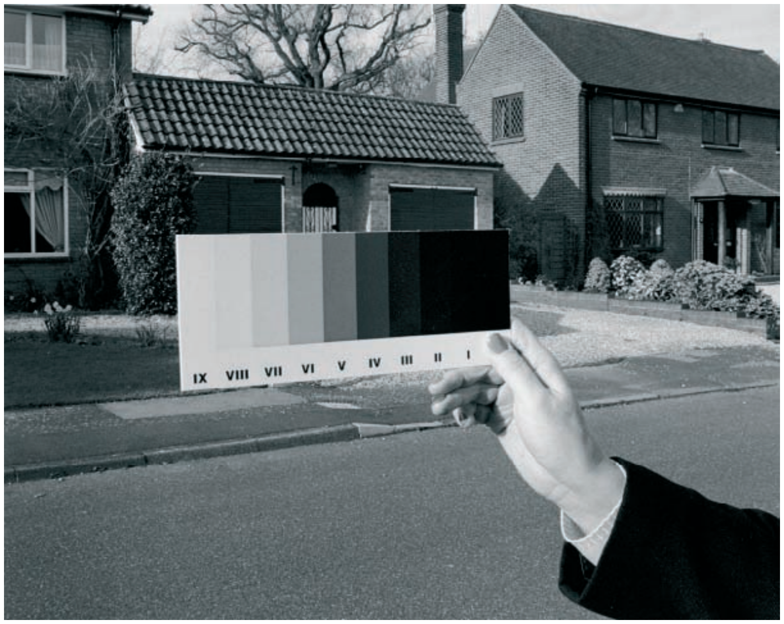
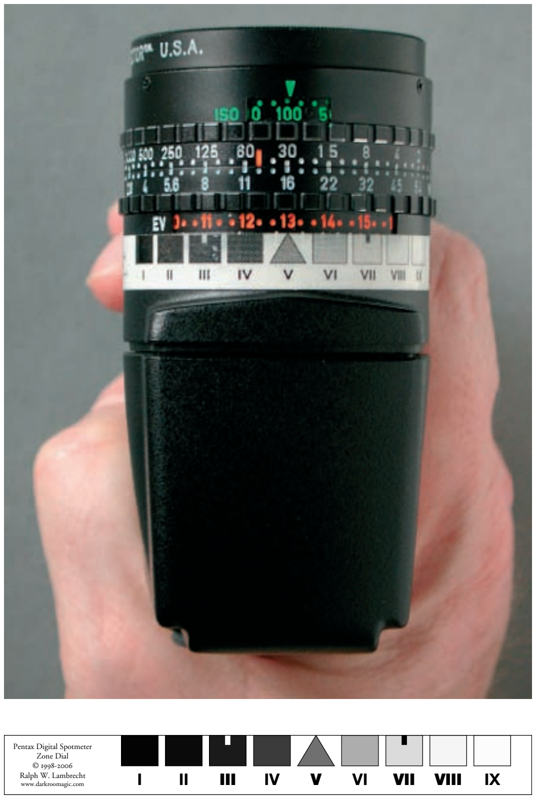


fig.3 The Zone Ruler is held at arm's length to compare the subject area in question with the print zone densities. Care must be taken that ruler and subject area are illuminated similarly, and that no reflection interferes with the evaluation. This is a handy support tool in the visualization process and has found a permanent place in the author's camera bag. However, artful visualization is successfully performed only by the human mind. Do not let the ruler stifle your creativity. You, the artist, are still in charge of the image.

# How to Build and Use a Zone Dial

## Additional functionality for popular spotmeters

fig.1 The customized zone dial for the Pentax Digital Spotmeter is a visual reference and will simplify zone placement. Zone III and VII are marked to place shadow and highlight details.



The lightmeter became part of the photographer's toolbox about 100 years after the invention of photography. Beforehand, photographers relied on empirical methods or a set of reference tables to determine the correct film exposure. Early exposure meters consisted of a holder for light sensitive paper and comparison step wedges with increasing densities. The paper was exposed for a given time to the same lighting conditions as the scene and then compared to the step wedge. The step, which was the closest to the exposed paper in density, gave an indication of the required exposure. Lightmeters have come a long way since then and have evolved to be accurate and dependable tools no photographer wants to be without. A serious Zone System practitioner has little or no alternative than to use a spotmeter capable of reading subject luminance within an angle of 1°. This narrow angle of acceptance permits convenient tonal placement of small but important subject detail. It may not be a coincidence that the invention of the Zone System followed the introduction of the first spotmeter in 1945.

### Reading the Lightmeter in Zones

Lightmeters, including spotmeters, are calibrated to suggest a film exposure, which will render the subject detail measured as an average or middle gray in the print. We refer to this as a Zone-V exposure. Consequently, if a luminance reading is taken with the meter, and this reading is used to determine film exposure without alteration, then we have placed the subject detail on Zone V. However, if we want the same detail on Zone IV, then we give 1 stop less exposure or 2 stops less to place it on Zone III. Alternatively, a 1-stop exposure increase will place the reading on Zone VI and so on. This technique is called zone placement and can be simplified with the aid of a custom zone dial.

Fig.1 shows a custom zone dial for the Pentax Digital Spotmeter. Feel free to copy it from the book for your personal use. Once applied to the meter as shown, a light reading can be placed on any zone, providing accurate tonal value placement without calculations.

### The Standard Zone Dial

It is very helpful for the student and the teacher to have a variety of educational props at hand when discussing photography in general and the Zone System in particular. Over the last few years, I have prepared many of these tools myself and most have proven to be very useful aids in my own classes, but the standard zone dial is by far the most popular. This is at least partially due to the fact that the pocket size version shown here can be used as a zone calculator and reference guide, while practicing the Zone System outside of the classroom. In addition, the use of the EV scale has reduced the complexity of similar devices to just two dials, which makes it easier to assemble and use.

All you need to build your own is a few pieces of cardboard, the use of a copy machine, some self-adhesive labels or glue, a small utility knife and some hardware to hold it together. Feel free to copy the illustrations in fig.2 from the book for personal use and glue them to the cardboard. At this point, carefully cut out the shapes, laminate with clear foil to give it some protection and use a bolt, nut and washer combination to assemble the two dials through the marked center points.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50076-4

The assembled zone dial (fig.3) works well with any lightmeter that provides film sensitivity adjusted EV readings. Most spotmeters do, one exception being the Pentax Digital Spotmeter, which needs an alternative zone dial as shown in fig.1. Take a shadow reading and place its EV number next to the desired negative zone. Now, take a highlight reading and its EV number location on the dial will reveal the negative zone onto which these highlights will fall at normal development. Taking additional readings, you can estimate zone placement for various subject areas.

Necessary development corrections can be predicted from the differences between highlight zone readings and their preferred values. If, for example, the shadow zone is read and placed, and the desired highlight for Zone VIII happens to actually fall onto Zone X, then an N-2 development is required.

The final decision on exposure can be made from any aperture/time combination in the window, because the EV numbers were provided as film sensitivity corrected values from the lightmeter. In addition, the standard zone dial provides a valuable overview of zone placement for the entire scene.

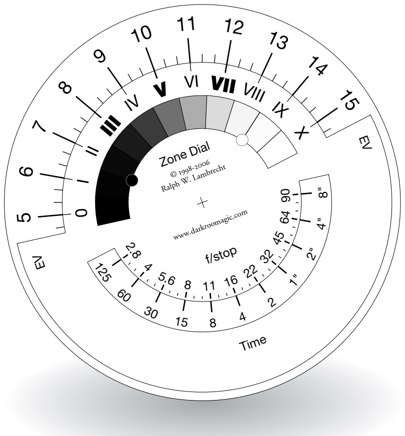

Zone Dial
© 1998-2006
Ralph W. Lambrecht
www.darkroomagic.com
f/stop
Time
EV
0 I II III IV V VI VII VIII IX X
5 6 7 8 9 10 11 12 13 14 15
2.8 4 5.6 8 11 16 22 32 45 64 90
125 60 30 15 8 4 2 1" 2" 4" 8"

fig.3 The assembled standard zone dial provides a handy reference to the way subject brightness will be represented in the final print.

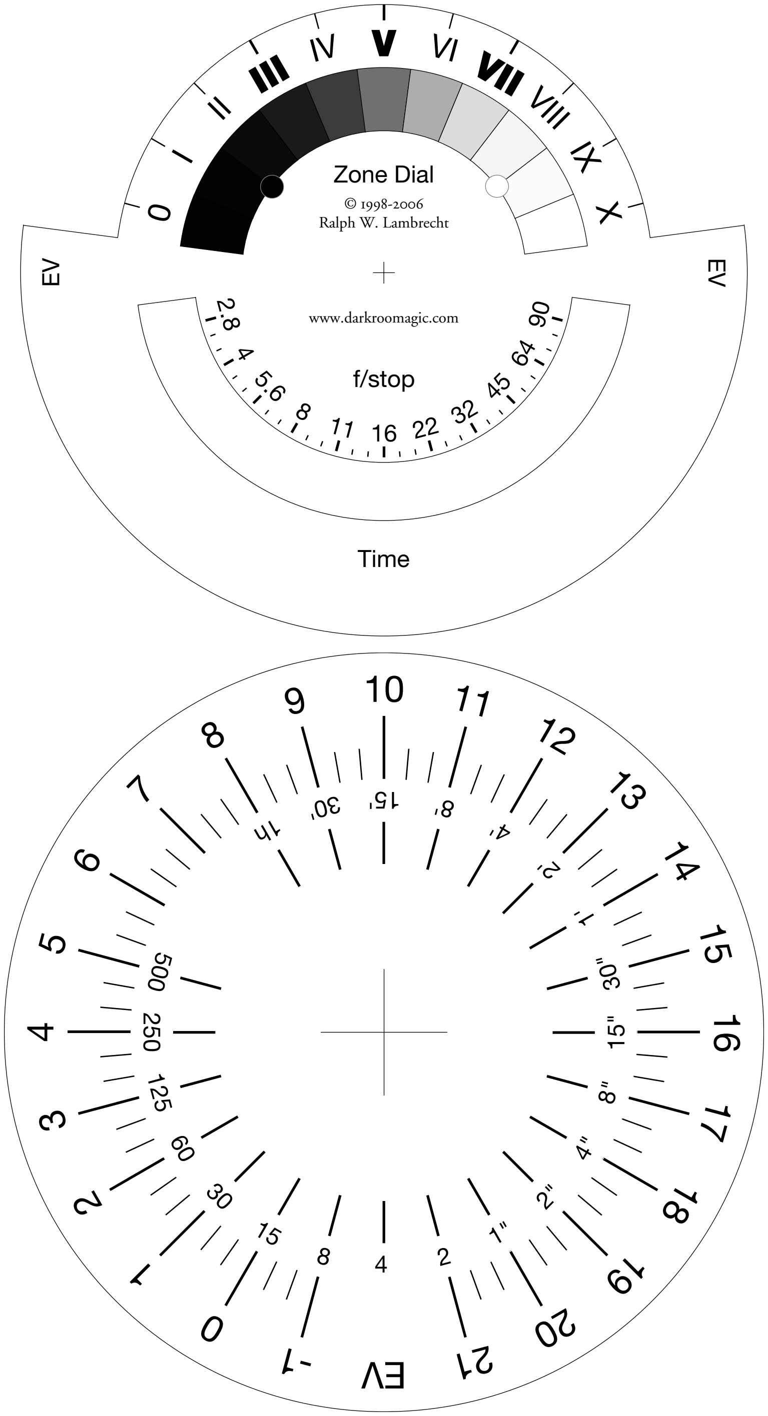

0 I II III IV V VI VII VIII IX X
Zone Dial
© 1998-2006
Ralph W. Lambrecht
www.darkroomagic.com
EV
EV
2.8 4 5.6 8 11 16 22 32 45 64 90
f/stop
Time
-1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
EV
500 250 125 60 30 15 8 4 2 1" 2" 4" 8" 15" 30" 1' 2' 4' 8' 15' 30' 1h

fig.2 Only two disks are required to make the standard zone dial. Zone III and VII are marked to place shadow and highlight details, and in addition, the tonality extremes are shown as black and white points at Zone I·5 and VIII·5.

# Make Your Own Shutter Tester

## Use your personal computer and this simple circuit to test your shutter

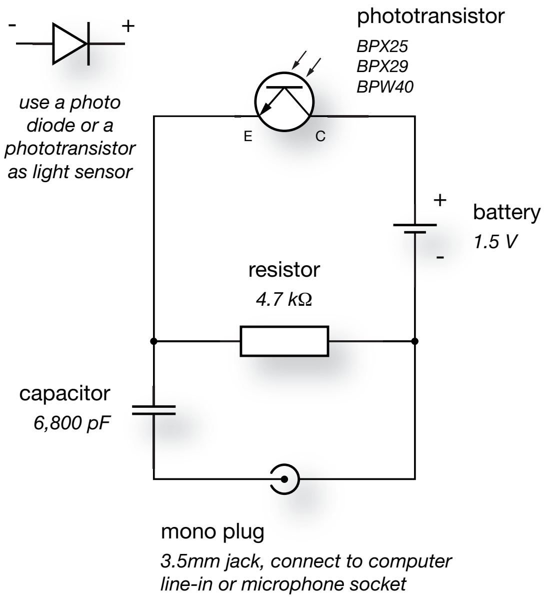

-
+
use a photo diode or a phototransistor as light sensor
phototransistor
BPX25
BPX29
BPW40
E
C
+
battery
1.5 V
-
resistor
4.7 kΩ
capacitor
6,800 pF
mono plug
3.5mm jack, connect to computer line-in or microphone socket

fig.1 The circuit for the self-made shutter tester contains only simple electronic components. Either a photo diode or a phototransistor can be used as a light sensor. A capacitor is included to protect highly sensitive microphone input circuitry. If the shutter tester is used with a less sensitive line-in socket, the capacitor may be bypassed to give a stronger signal.

At the time of this writing, we cannot find an affordable shutter-speed tester available on the market. After investigating a number of alternatives, however, we can report on an elegant and simple solution to make your own.

Before diving in, it is worth noting that this method relies upon the shutter working regardless whether the camera body is open or closed. Obviously, this excludes all digital cameras and some modern film cameras, which restrict shutter operation while the film back is open or removed. All other roll-film cameras and large-format lenses can have their shutters measured with this useful self-made device.

The concept is deceptively simple. A light-detecting sensor is placed behind the camera body or lens, facing a light source placed in front of it. A convenient source of light is a battery-powered torch or an ordinary desk lamp. The circuit in fig.1 produces a small voltage pulse when the light, falling on the sensor, changes abruptly. This voltage pulse is recorded through the microphone or line-in socket of a personal computer with the aid of an audio-capture program. The program must be able to record a high-frequency signal and display the 'audio' waveform on a timeline. Most PC sound cards are supplied with such software, and an internet search finds several freeware or shareware audio-capture programs.

### Light Sensor

The circuit in fig.1 relies on a reverse biased photo diode or transistor as a light sensor, which change their resistance corresponding to a change in incident light. Compared to traditional light-dependent resistors, photo diodes and transistors react virtually instantaneously. The voltage at the junction of the sensor and resistor changes with light level, and the change is transmitted via the capacitor to the microphone input. The capacitor blocks any DC voltages and lets just the transients pass. A positive pulse occurs when the light level increases and a negative pulse when the light is reduced. The component values are not overly critical and are easily obtained from a hobby electronics store. To make the assembly more robust, it is mounted in a small plastic box, preferably black, with the sensor mounted behind a small hole (fig.2).

### Setup

Conducting the test with a camera body, the self-made shutter tester is carefully positioned, facing the film rails but without touching the delicate shutter blades.

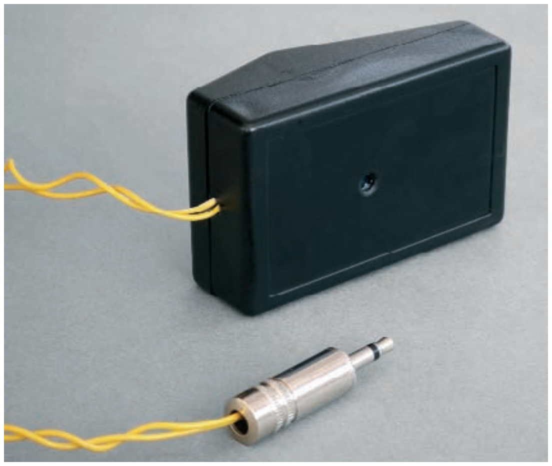


fig.2 The self-made shutter tester is connected to the microphone or line-in socket of a personal computer.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50077-6

A few rubber bands or some tape will safely hold the tester in place. Depending on whether one is checking a leaf or a focal-plane shutter, the lens is attached, and set to a working aperture, or removed from the camera body altogether. The light source is placed in front of the camera, facing lens or lens opening (fig.3). The camera or lens shutter is wound, and the 3.5mm jack of the shutter tester is connected to the microphone or line-in socket of the computer.

Run the capture software and start a new 'recording'. Immediately press the shutter and stop the recording after the shutter closes. Several seconds of recording will have occurred, so you must use the editing tools in the software to find and extract the two pulses. Now, expand the timeline to see them clearly and use the selection cursors to measure the time between the pulses, halfway up the positive pulse and halfway down the negative pulse, as shown in fig.4.

A little experimentation may follow where it could be necessary to alter the 'microphone' gain or the light intensity to get the signal within the range of the audio hardware. If there is no signal, it may be that the photo diode or transistor is connected the wrong way around. Note that the line-in socket of a sound card is less sensitive than the microphone socket, and therefore, it may require a stronger illumination of the light sensor. To protect your computer hardware, always start with a low setting and slowly increase illumination, as required, to get a stronger signal.

For the example shown in fig.4, the freeware audio-capture program 'Audacity' was used on an Apple Macintosh. The screen shots show the different waveforms recorded by a microphone and a line-in socket for a 1/500-second shutter setting. In this test, the audio sample frequency was 44.1 kHz, and 78 samples were captured between the leading edge of the two pulses. This equates to an effective shutter speed of 78/44,100 or 1/565 second, which causes a slight underexposure but is still a good result for a mechanical shutter.

Make a separate recording for each shutter setting, calculate all effective shutter speeds and record them in a list. Optionally, also calculate the shutter-speed deviations and chart the resulting f/stop errors for the entire range (fig.5). As underexposure is more harmful to negative film than overexposure, slow shutters are better than fast shutters. This explains why the recommended acceptance criteria are more stringent towards fast shutter speeds. For all calculations, remember that the shutter speed markings on a camera or lens are rounded approximations. The true sequence is 1, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, 1/128, 1/256, 1/512 and 1/1024 of a second.

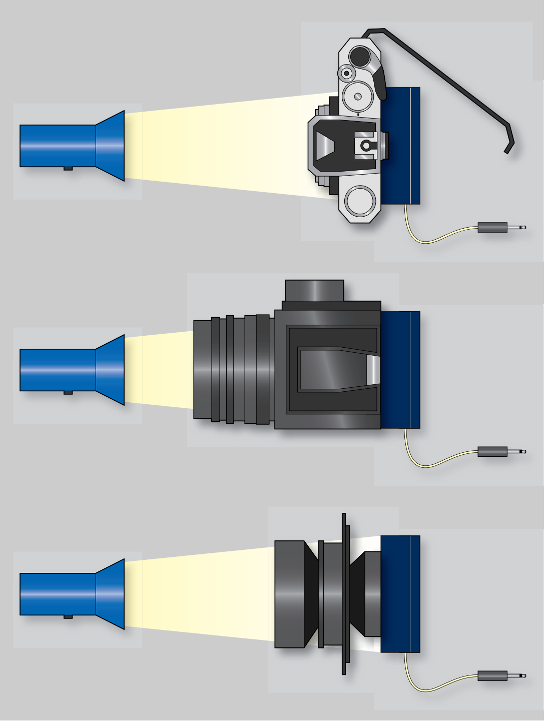
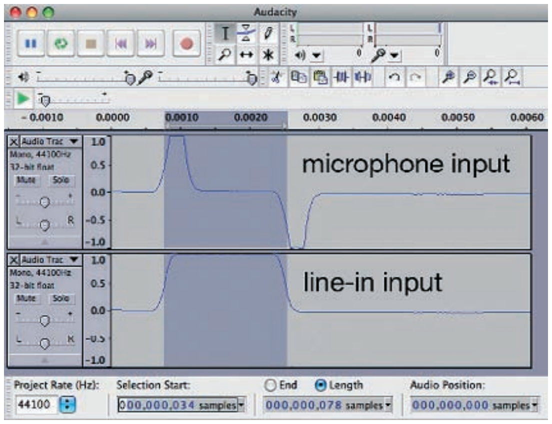


fig.3 Depending on the type of shutter to be tested, the shutter tester is positioned behind camera or lens, and a light source is placed in front of the camera.



Project Rate (Hz): 44100

Selection Start: 000,000,034 samples

Length: 000,000,078 samples

Audio Position: 000,000,000 samples

fig.4 Audio-capture software is used to measure the number of samples between two light pulses, which, in turn, equates to the effective shutter speed.

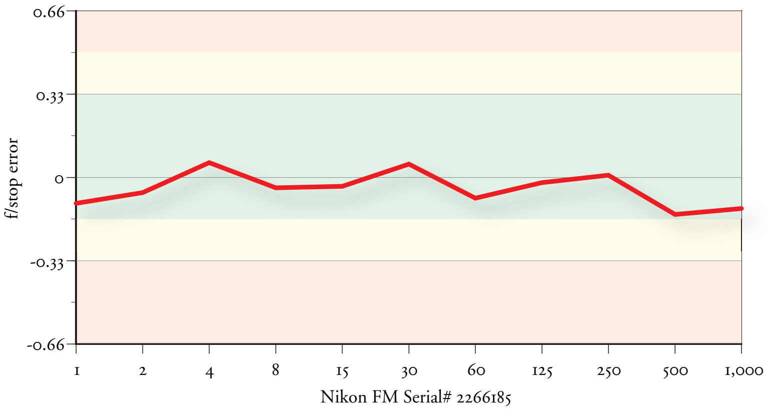


fig.5 Shutter-speed deviations can be charted as f/stop errors. As underexposure (fast shutter) is more harmful to negative film than overexposure (slow shutter), the acceptance criteria are more stringent towards fast shutter speeds.

# Make Your Own Test Strip Printer

## A useful tool for localized and continuous test strips

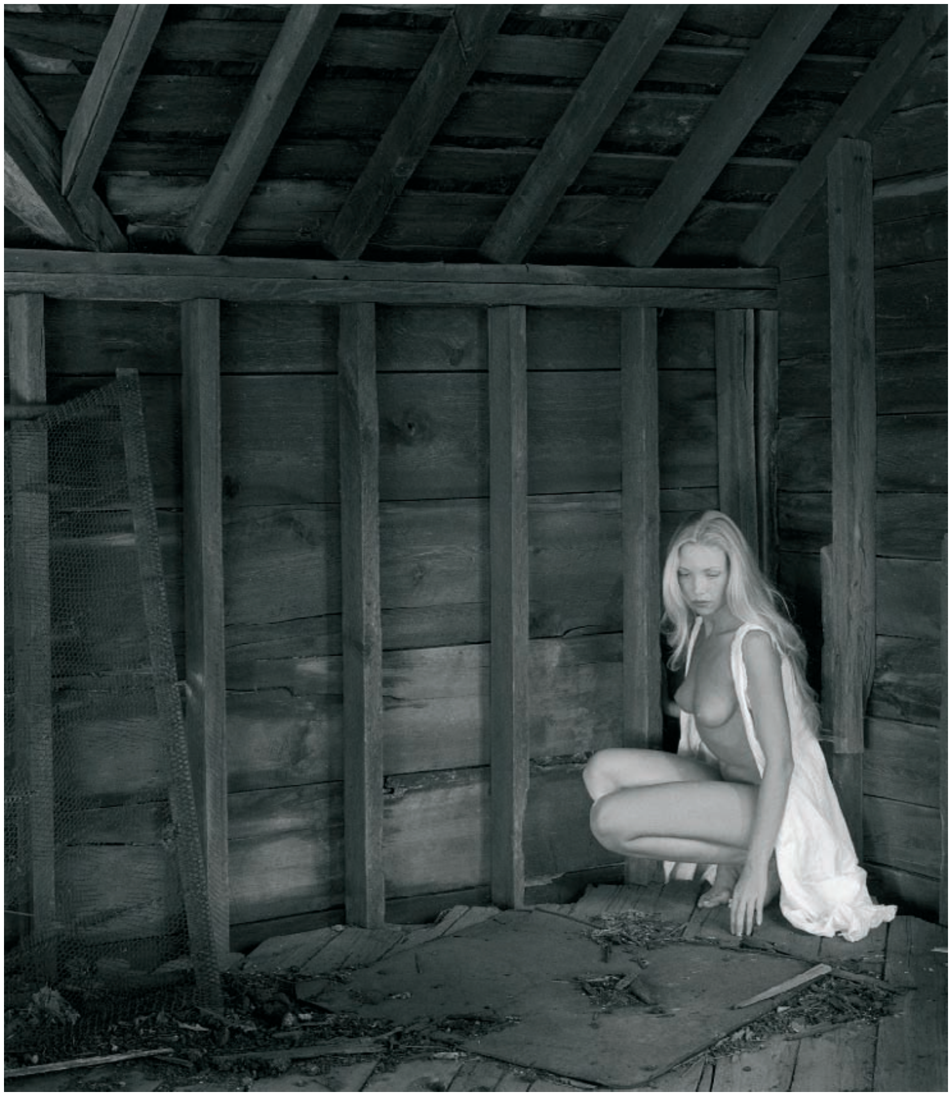


fig.1 The important tonal values of the highlights are limited to one area of the print. This is a typical image to demonstrate the need for a localized test strip.

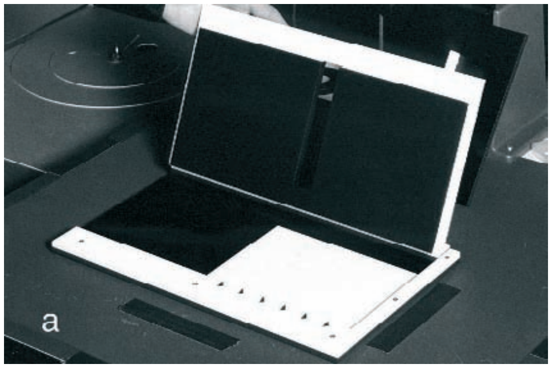
The creation of a high quality print is far easier with the help of an informative test strip. A few minutes of time can give the darkroom practitioner test results, revealing the right exposure and paper grade for a particular image. Additional test strips, made at potential problem areas of the image, can give us useful information to improve the print with dodging and burning techniques. An organized approach to test strips can replace an inefficient trial and error method, ultimately saving time and paper and yielding more information than any electronic analyzer.

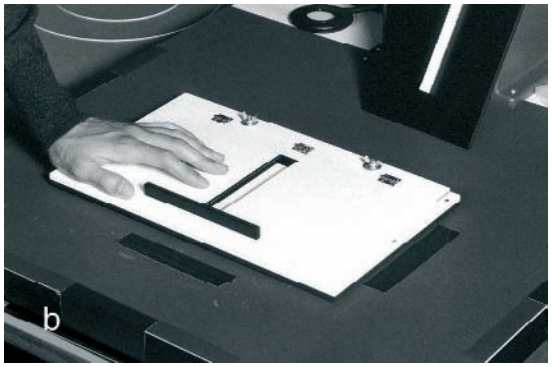
There are two schools of thought when it comes to test strips. First, there is the localized test strip, concentrating on only one particular area of the print. This is typically a delicate highlight area, concerned with the lighter tonal values of the image. Second, there is the continuous test strip, concentrating on the entire area of the print. The choice of which type of test strip to use depends entirely on the image.

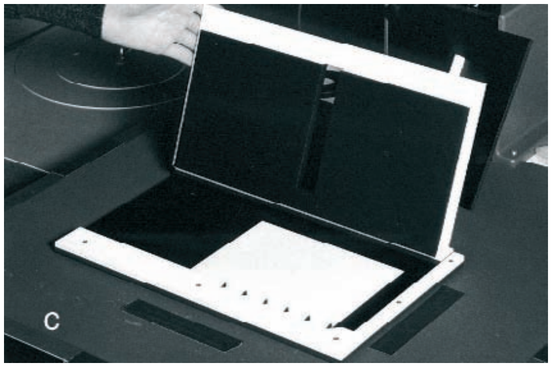
It is simple enough to create a continuous test strip. A small piece of photographic paper is placed under the enlarger and a base exposure is applied. Then, the paper is partially covered by an opaque card and an additional exposure is made. This process is repeated until five to seven different exposures are made. Creating a localized test strip is a bit more involved. In this case, the paper has to be moved precisely each time, since the exposure must be made from the same area of the image. This cannot be done accurately unless some kind of paper guide is used. Several versions of such a guide are available commercially, but to my knowledge none of them can be used to create both localized and continuous test strips.

Therefore, I decided to design and make my own test strip printer. It has since become a standard tool in my darkroom, and is used to determine exposure and contrast for every new print. This test strip printer

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50078-8







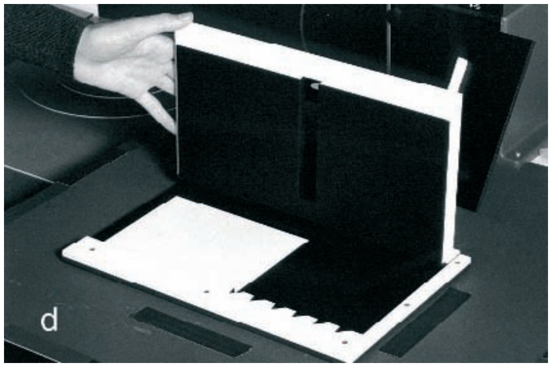
makes use of regular 5x7-inch pieces of paper. I have a box of this size for every paper type I use on a regular basis. For rarely used and special papers, it is often easier and more economical to cut a few pieces from the existing stock. I'd like to explain first how to use the test strip printer with the help of two example images. The instructions on how to build your own test strip printer will follow at the end of this chapter.

## Localized Test Strips

The first image is shown in fig.1 and was taken in an abandoned farmhouse in Howell, Michigan USA. The model and I climbed to the attic of the farmhouse using a wooden ladder of rather questionable structural integrity. This ruled out the use of any professional lighting equipment, but I was pleasantly surprised by the amount of natural light coming through several cracks in the roof. The Hasselblad 501C, fitted with the Carl Zeiss Planar 2.8/80, was supported by a tripod to allow for an exposure time of 1 second at f/8 on TMax-400 film. The model was placed in one of the corners of the attic. In this position, all lines generated by the surrounding beams and panels lead the eye towards the model. The white dress and the blond hair are the focus point of the image.

A continuous test strip across the entire image would not be much help in this example, where the highlights are primarily located in one area of the print. Therefore, we'll make a localized test strip to establish a basic print exposure, which holds these sensitive tonal values close to paper white, without losing their delicate highlight detail.

First, the negative is placed into the enlarger and the desired magnification determined. Then, the narrow window of the test strip printer is placed into



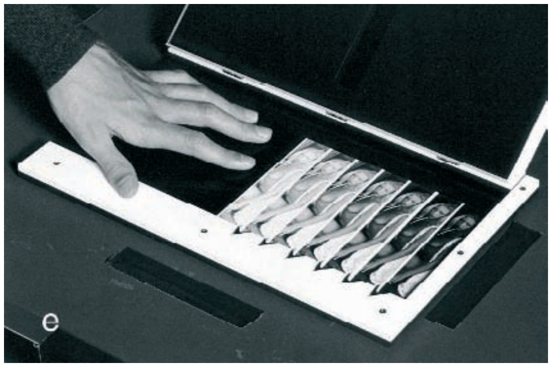
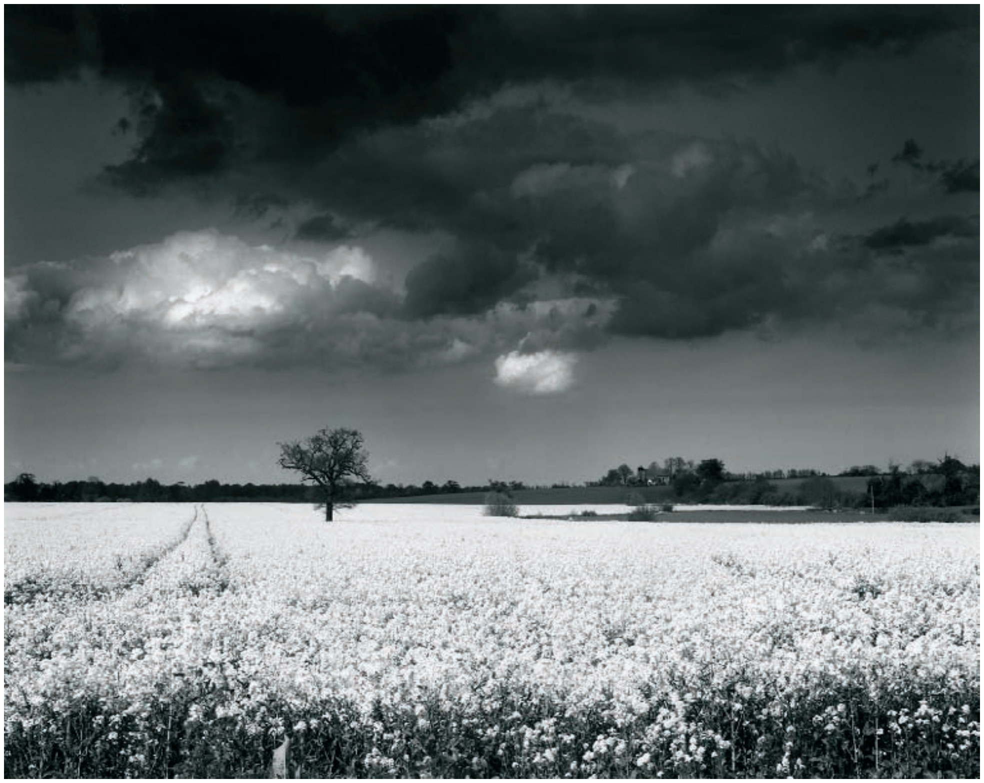


fig.2a-e A localized test strip is the best choice if the governing highlights are concentrated in a relatively small area of the image.

position, catching the area of interest. A 5x7-inch piece of white scrap paper can be used to help with this task. Initially, your best guess at exposure time, f/stop and contrast will do. Try to err on the low side of the contrast. It is better to slowly increase the contrast, rather than having to reduce it. It will put you in control to give up shadow detail, after you have seen it.

At this point, it is time to turn on the safelights and to make the first exposure. Push a piece of 5x7-inch paper into the bottom right-hand corner of the test strip printer (see fig.2a), close it (see fig.2b), and expose the first test strip. Open the test printer and move the paper to the left by one notch (see fig.2c). The large triangle cutouts make this a simple task even when in the dark. I place a finger in the notch and move the paper until it touches the finger from the left. The second exposure time should differ from the first by 1/3 stop for rough estimates, 1/6 stop for normal test strips and a 1/12 stop for fine-tuning the image. Use increments of 25, 10 or 5%, respectively, if you would rather work in percentages. Continue with these increments until all seven exposures have been made (see fig.2d). The final test strip is shown in fig.2e after processing was completed. It shows how the test strip printer produced increasingly darker exposures for the same area of the image. It is not difficult to determine a final exposure time for the highlights from this test strip. Proper shadow detail is the next priority and is controlled with the appropriate paper contrast. This can be tested in a similar way, but see 'Fine-Tuning Print Exposure and Contrast' for an alternative approach. You can also prepare localized test strips for problem areas to determine corrective dodging and burning times, while achieving final tonal control and slowly creating a printing map for your image.

fig.3 The tonal values of the significant highlights are spread across the bottom of the print. This is a typical image to demonstrate the need for a continuous test strip.

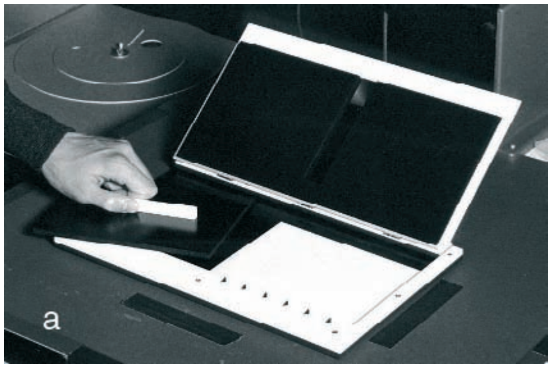


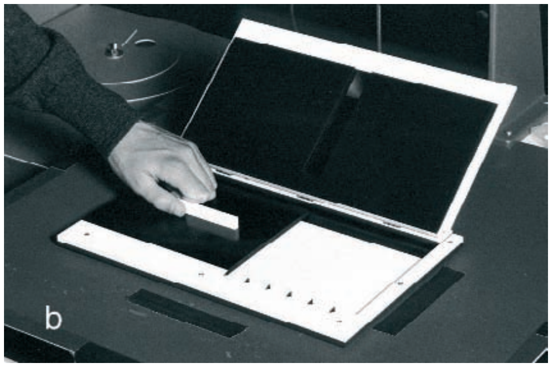
## Continuous Test Strips

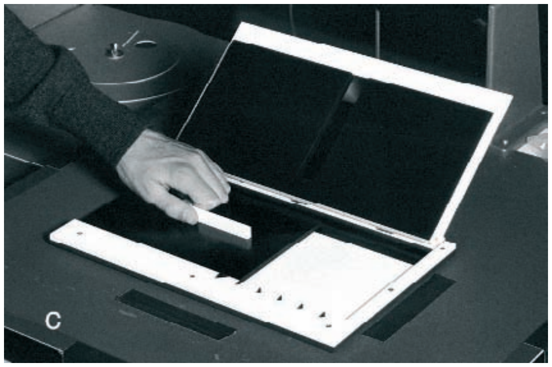
The second image is shown in fig.3 and it was taken in a rape field close to my home in Essex, England. I drive by this field twice a day, on my way to and from work, and I had watched the progress of the vegetation. When the field finally had the distinctive yellow color, all I needed was a stormy cloud pattern to give the image the right atmosphere and bright sunshine to light up the field in the foreground. I had to wait for a weekend in May of 1999 for the conditions to be just right. The Toyo 4x5 metal field camera and the Nikkor-W 5.6/210, fitted with the Orange filter, were supported by my heaviest tripod to give solid support for an exposure time of 1/15 second at f/32 on TMax-400 film. The session still required more than two hours of patience for just the right light and cloud pattern. This type of picture is usually taken in color, but I visualized the field to be almost white, with a prominent white cloud contrasting the otherwise dark sky.

Again, we are best off to begin by establishing a basic print exposure, which holds these sensitive tonal values close to paper white, without losing their delicate highlight detail. The proper shadow detail will be established later with the proper paper grade. The prominent highlights are spread evenly across the entire image foreground with almost identical tonal value from left to right. A localized test strip would work well, but would take more time to prepare. Therefore, we'll make a continuous test strip this time.

As done before, push a piece of 5x7-inch paper into the bottom right-hand corner of the test printer (see fig.4a), but this time leave the cover open. Expose the entire test paper for your anticipated minimum exposure time. Then, use the black pedal and cover the left strip, again with the aid of the large notches (fig.4b).







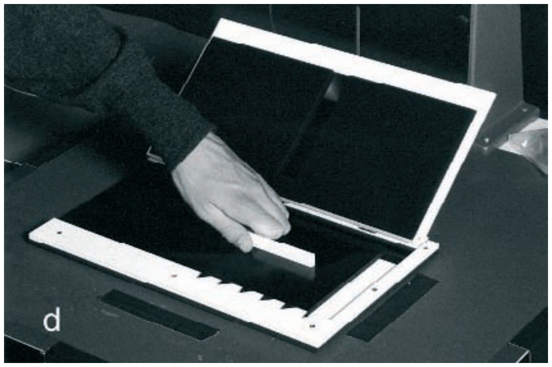
Expose for an incremental 1/3, 1/6 or 1/12 stop, depending on how fine you want the increments to be, or use additional increments of 25, 10 or 5%, respectively, if you prefer. Continue with these increments (fig.4c) until all seven exposures have been made (fig.4d). The final test strip is shown in fig.4e after processing was completed. It shows how the test strip printer produced continuously darker exposures across the image. It is easy enough to determine a final exposure time for the highlight from this test strip. I also use this method to test for appropriate edge-burning.

## How to Make Your Own

To my knowledge, such a versatile test strip printer is not commercially available. Therefore, I decided to make my own. Fig.5 shows an exploded view of all parts, the bill of materials and the basic dimensions. I used 1/4-inch opaque plastic sheets in black and white as the base material. The colors were chosen so that the photographic paper is only in contact with black material. However, all other visible surfaces are kept white to provide the highest possible contrast, which will aid handling in the darkroom.

The tools required for this project include a table-saw, a handsaw, a drill, a screwdriver, some adhesive, a file and some clamps. If you don't feel confident operating these tools, I suggest you make the test strip printer from thick cardboard. The tools required are then reduced to a sharp trimming knife and some glue. You could also replace the hinges with durable tape.

Cut the pieces to the dimensions shown in fig.5 and smooth the edges with sand paper. The saw-tooth pattern of the white scale (2) takes a little patience, but its accuracy is important. Glue or screw the white scale to the black base plate (1), while aligning the front



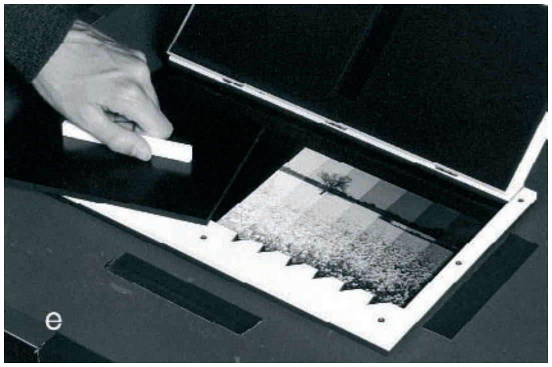


fig.4a-e A continuous test strip is the best choice, if the governing highlights are spread over a relatively large area of the image.

| No | Part Name | Dimensions [in] |
|---|---|---|
| 1 | base plate | ¼ x 8 ½ x 14 |
| 2 | scale | ¼ x 8 ½ x 14 |
| 3 | lower cover | ¼ x 6 x 13 ½ |
| 4 | hinge plate | ⅜ x 15/16 x 13 ½ |
| 5 | upper cover | ⅛ x 7 x 14 |
| 6 | cover handle | ¼ x ½ x 5 ½ |
| 7 | foot (5) | ø ½ |
| 8 | screw (2) | ø ⅜ x 1 |
| 9 | wing nut (2) | ø ⅜ |
| 10 | washer (4) | ø ⅜ (large) |
| 11 | hinge (3) | ⅝ x ¾ |
| 12 | pedal | ¼ x 5 ½ x 7 ½ |
| 13 | pedal handle | ¼ x ½ x 4 ½ |

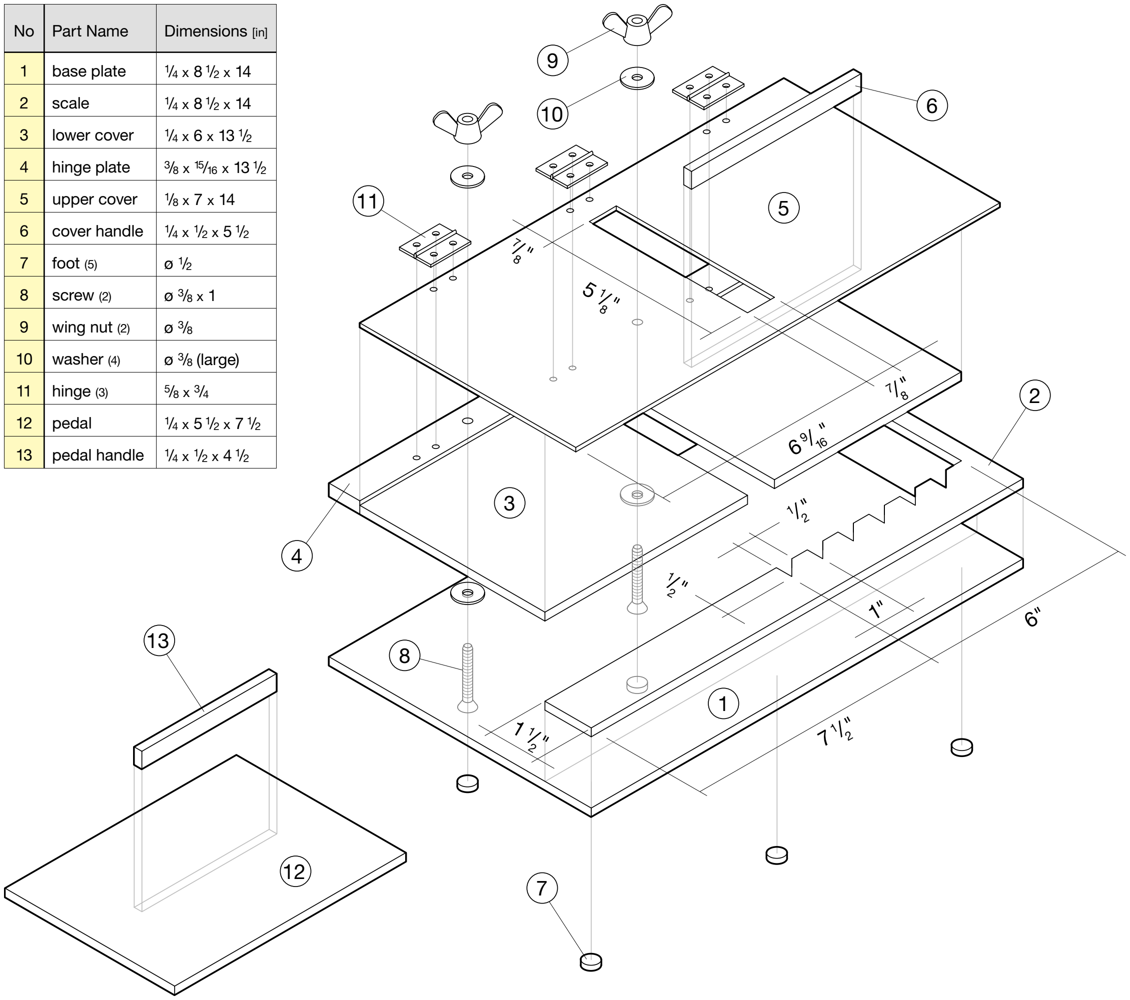


fig.5 The exploded view and the basic dimensions of the test strip printer

and right edge. Using screws rather than glue has the benefit that a flush fit between the two pieces is realized. This will keep the paper from potentially being caught in a glue gap. Now, glue the white upper cover (5) to the black lower cover (3) while aligning the back edge and both sides. Next, glue the black cover handle (6) to a convenient center location on top of the upper cover. Similarly, glue the white pedal handle (13) to the black pedal (12) centered in both directions.

Clamp the white hinge plate (4) to the base plate while aligning the back edge, and drill two 6.5-mm holes. You can distribute the hole pattern as you wish, or as I did, 1/3 from the sides. These holes will be used to hold the hinge plate in place with screws (8), washers (10) and the wing nuts (9). Place the cover assembly on the base plate and push it against the scale at the front and right hand edge. Attach the hinges (11) with small screws or glue. As a final touch, place a few self-adhesive feet (7) to the bottom of the base plate.

Your test strip printer is now ready for your first print (fig.6), and I hope that you find yours as useful as I find mine. It is put to good use for all my printing now.

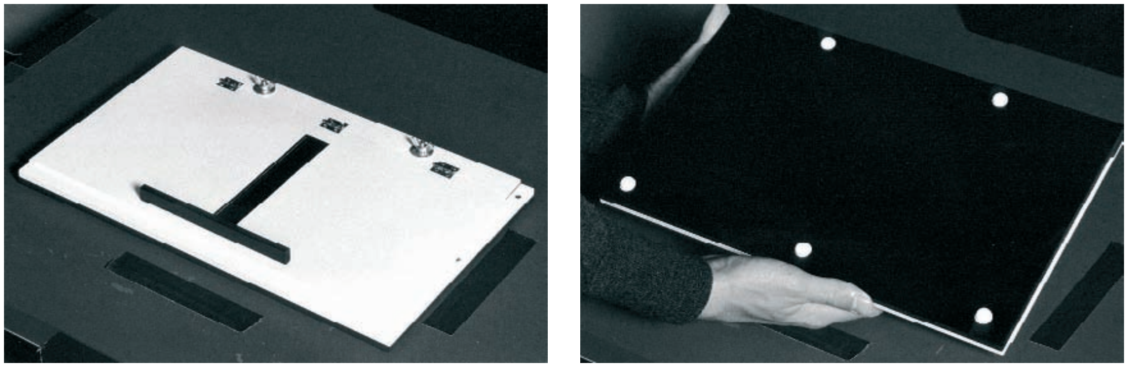


fig.6a-b The final test strip printer assembly. Five rubber feet ensure that it stays in place during operation and test exposures.

# Make Your Own Burning Card

## A useful tool for fine print control

Dodging and burning are creative printing controls, which are often necessary to emphasize certain areas of the image. A 'straight' print might show some areas too light, while others are too dark. Adjusting the overall contrast, in an attempt to capture both ends of the print scale, may give a 'weak' print. For a more expressive image, optimize the local contrast in areas of interest and tweak the shadows and highlights with dodging and burning techniques to their individual optimum.

Many experienced printers simply use their own hands to cover or direct the light path to certain areas of the image. Others prefer the use of purchased or self-made templates to achieve similar results. To dodge, I use a piece of cardboard, which is mounted to a thin piece of wire. Its shape is sometimes image dependent but, most often, it is just a small circle or rectangle. My burning tool is a self-made template, which is flexible enough to help me with almost all of my images. It only takes about an hour to make it, and I will explain later how it is done. But first, I'd like to show you a sample image where the self-made burning card came in handy (fig.1).

### Silver Maple Leaf

This image was taken in my backyard in Farmington Hills, Michigan USA in July of 1997, at the end of a rainy day. The reverse side of a silver maple leaf is very bright and makes a strong contrast to the dark surrounding leaves. I fixed the Hasselblad 501C to my shortest Manfrotto tripod, which I originally bought because it fits well into my suitcase. In this case, however, it was ideal, because it allowed me to get close to the ground and this scene. The Carl Zeiss Planar 2.8/80 was mounted to the camera and the close-up filter permitted a focal distance of about 60 cm. The camera back was loaded with Kodak's TMax-100 film, which I down-rate to EI 64 for normal development.

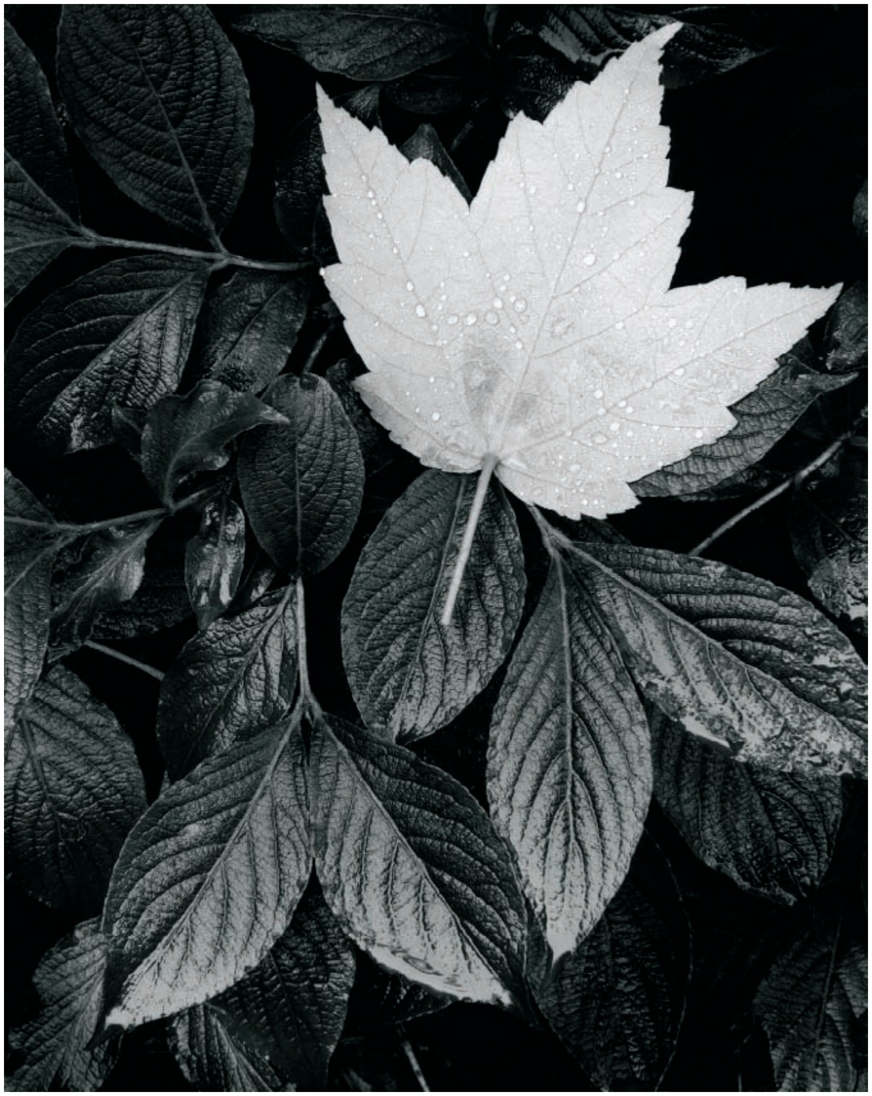


fig.1 Adjusting overall contrast with the aim of a 'straight' print is not always advisable. The expressive image often benefits from final printing controls like dodging and burning.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50079-X

I wanted detail in most of the dark background leaves and placed them on Zone III. The brightest parts of the leaf fell, consequently, onto Zone IX. However, I was hesitant to give N-1 development, because I was concerned about losing local contrast. I waited for the light breeze to hold for a moment and exposed at f/16 for 1 second. The negative turned out just as I expected with most of the bright leaf being well into Zone IX. Again, I hesitated to lower the paper contrast to protect the local contrast. I settled for grade 2.5, accepting that the leaf would be too light on the work print. Most of the shadows were as I wanted them, but there was too much detail in some areas, which distracted from the leaf. These areas were burned down with 2/3 stop additional exposure. Then, I raised the contrast to grade 4 and added a burn-in exposure to the leaf until it had the right level of highlight detail. The increased paper contrast allowed the fine details of the leaf to appear, without turning the rest of the leaf into an unnatural dirty gray.

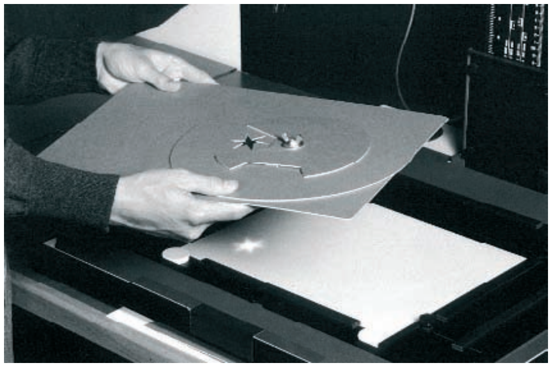


fig.2 The burning card has three layers, which are held together by a screw, a washer, and a wing nut. A red cardboard was chosen as the base material. It is light enough to see the projected image, but all reflected light is of a harmless wavelength for the photographic paper.

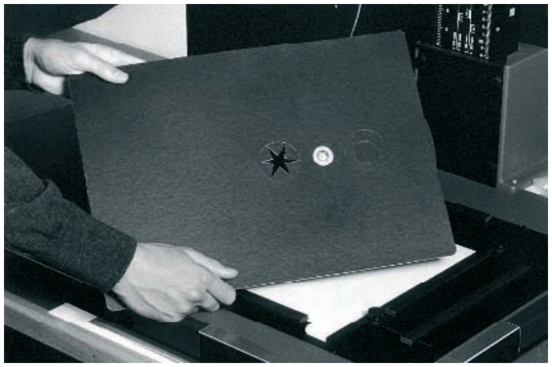


fig.3 The underside of the burning card is painted flat black to prevent any light from reflecting back to the paper. The bottom card has two holes, one for the center pivot and another for hard to reach areas in the corner of the image.

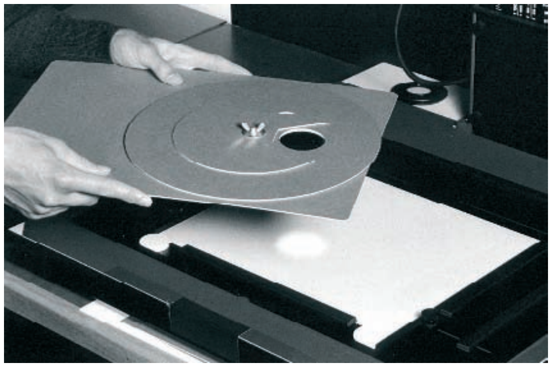


fig.4 The circular card in the center has several hole patterns to adjust the light path to specific applications. This light path can be further modified with the top card, by covering the chosen hole pattern partially. This way, many customized shapes are possible.

## How It Works

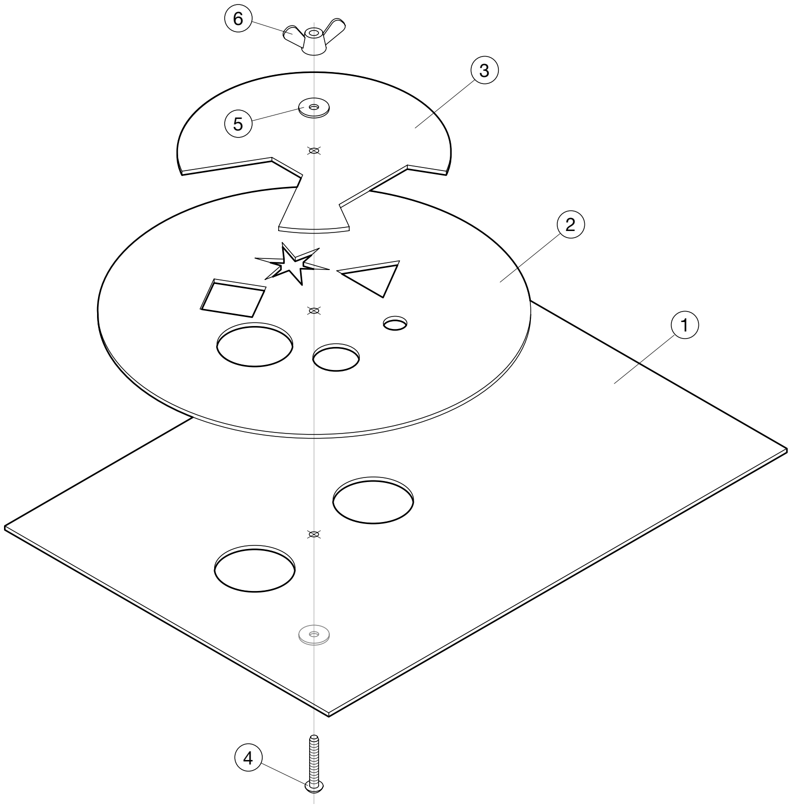
Fig.2 shows the burning card, which consists of three cardboard layers, held together by a screw, a washer, and a wing nut. This makes it easy to unlock the cards, select the hole pattern of choice and then lock the cards together again to maintain a stable selection during the burning process. A cardboard stock, red on top and white underneath, was chosen as the base material. The red side reflects enough light to see the projected image clearly, but all reflected light is reduced to a wavelength harmless to the photographic paper.

Fig.3 shows the underside of the burning card and how it is painted flat black to prevent any light from reflecting back to the paper. The bottom card has two holes, one for the center pivot and another for hard-to-reach areas in the corner of the image. Using the outside hole for corner-burns maintains light protection for the rest of the image.

Fig.4 shows the center card and one of its several hole patterns, which are used to adjust the light path to specific applications. This light path can be further modified with the top card, by partially covering the chosen hole pattern. A half-moon shape is easily created by covering half of the circular hole, or a triangle is created by covering the square diagonally. This way, it is possible to produce countless customized shapes.

## How to Make Your Own

Any art store sells sturdy poster board, such as I used for the burning card, in many sizes and colors. If you are lucky, you'll find the two-tone variety. The optimum card would be medium red on one side and flat black on the other. Otherwise, select the red board and spray-paint one side flat black, before you start cutting it. They are usually sold in DIN-A1 (2x3 feet) and that will be more than enough to make an DIN-A3 (11x17 inches) card and leave you with



| No | Part Name | Dimensions [in] |
|---|---|---|
| 1 | base plate | 12 x 18 |
| 2 | pattern disk | ø 11 |
| 3 | modifier disk | ø 7 |
| 4 | screw | ø 3/8 x 1/2 |
| 5 | washer | ø 3/8 (large) |
| 6 | wing nut | ø 3/8 |

fig.5 The exploded view and the basic dimensions of the burning card

enough material to make a variety of small dodging tools. You can use the exploded view in fig.5 and the bill of materials as a rough guide for dimensions, but it is probably best if you customize the sizes and the hole patterns to meet your own needs.

Cut a cross-shape, rather than drilling a hole, where you want the screw to penetrate the cardboard. The extra material will help the screw to cut its own thread and make a more reliable fit. Use a large 'automotive' washer, because it will distribute the clamp force over a larger area and reduce wear. Make sure that all holes are on a centered path around the screw, because the holes in the bottom card need to be able to reveal every hole pattern completely. You can do so using a drafting compass to mark a large circle with the fixing hole as its center. Now, place the center of every hole pattern, in even increments, along the perimeter of that circle. I'm sure you will enjoy having this tool.

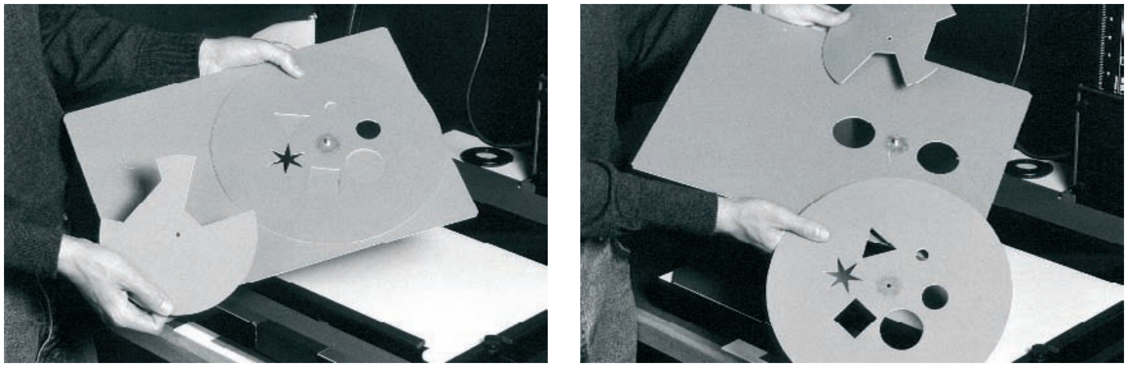


fig.6a-b The burning card is being disassembled. Only one screw holds the three cards in place and provides the pivot point for the hole pattern.

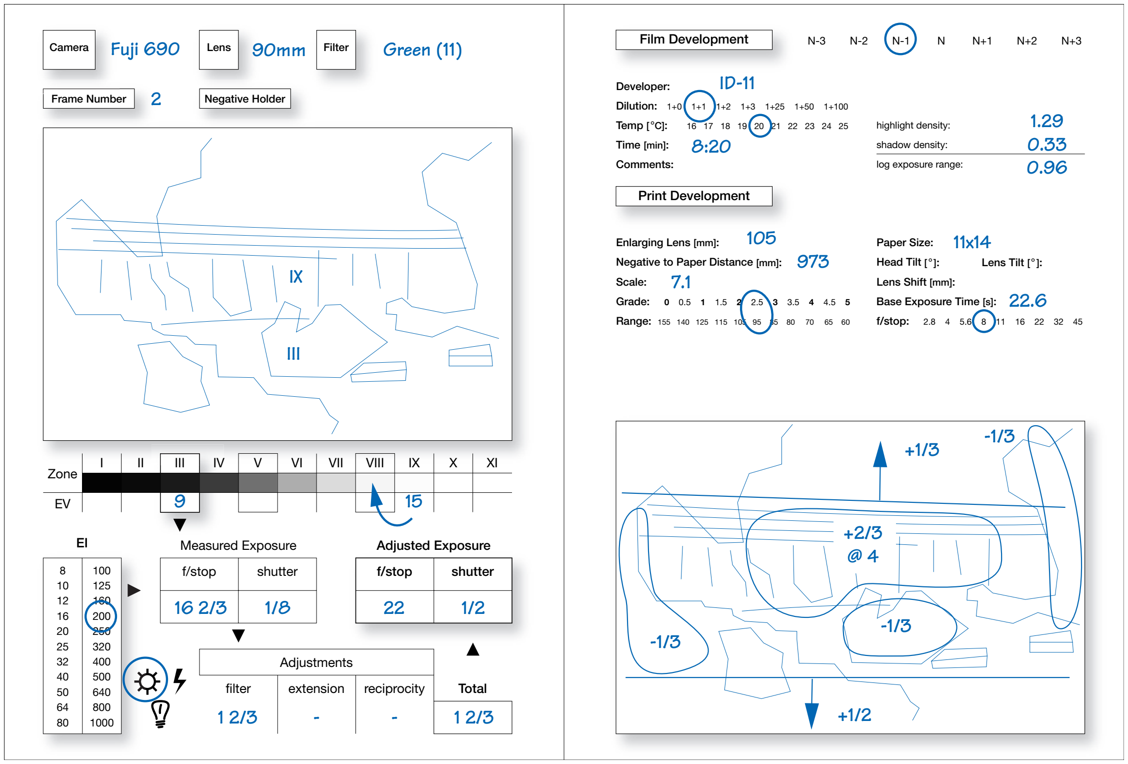
# Exposure, Development and Printing Records

## A small investment in time with high returns

There is no doubt about it. Film exposure, development and printing records are invaluable. The ability to recall scene metering, filtration, exposure and development, or the final print manipulation in the darkroom will certainly minimize the time required to fine-tune one's technique. It is also the only way to find out why things did not turn out as expected or to reliably repeat the things which did. Depending purely on memory is a guarantee for failure.

Unfortunately, taking notes during the photographic process is rather boring, often cumbersome, potentially disruptive to the creative process, possibly time consuming, and is, therefore, generally considered to be a burden to most photographers. It seems reasonable after an hour or two in the darkroom to spend a few moments to scribble down how a print was dodged and burned, but pulling out pencil and pad in the field every time an exposure is committed

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50080-6



**Camera** Fuji 690 **Lens** 90mm **Filter** Green (11)

**Frame Number** 2 **Negative Holder**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Zone | I | II | III | IV | V | VI | VII | VIII | IX | X | XI |
| EV | | | 9 | | | | | | 15 | | |

| EI | |
|---|---|
| 8 | 100 |
| 10 | 125 |
| 12 | 160 |
| 16 | [✓ 200] |
| 20 | 250 |
| 25 | 320 |
| 32 | 400 |
| 40 | 500 |
| 50 | 640 |
| 64 | 800 |
| 80 | 1000 |

Measured Exposure

| f/stop | shutter |
|---|---|
| 16 2/3 | 1/8 |

**Adjusted Exposure**

| **f/stop** | **shutter** |
|---|---|
| 22 | 1/2 |

| Adjustments | | | |
|---|---|---|---|
| filter | extension | reciprocity | **Total** |
| 1 2/3 | - | - | 1 2/3 |

**Film Development** N-3 N-2 [✓ N-1] N N+1 N+2 N+3

**Developer:** ID-11

**Dilution:** 1+0 [✓ 1+1] 1+2 1+3 1+25 1+50 1+100

**Temp [°C]:** 16 17 18 19 [✓ 20] 21 22 23 24 25

**Time** [min]: 8:20

**Comments:**

highlight density: 1.29

shadow density: 0.33

log exposure range: 0.96

**Print Development**

**Enlarging Lens** [mm]: 105

**Negative to Paper Distance** [mm]: 973

**Scale:** 7.1

**Grade:** **0** 0.5 **1** 1.5 **2** [✓ 2.5] **3** 3.5 **4** 4.5 **5**

**Range:** 155 140 125 115 105 [✓ 95] 85 80 70 65 60

**Paper Size:** 11x14

**Head Tilt [°]:** **Lens Tilt [°]:**

**Lens Shift** [mm]:

**Base Exposure Time** [s]: 22.6

**f/stop:** 2.8 4 5.6 [✓ 8] 11 16 22 32 45

fig.1 This is a standard form to keep exposure, development and printing records together on one sheet. A blank record sheet is supplied in the 'Tables and Templates' chapter. Feel free to copy it from there for your personal use, but please take care not to damage the book.

(based on an original by Ansel Adams)

to film seems like too much administration to most of us. However, the benefits of committing memory to paper clearly outweigh the labor involved, especially if the labor can be minimized through a bit of planning and the use of some templates, which eliminate repetitive tasks. I don't particularly like taking records either, but I have nonetheless recorded film exposure and development data for most, and printing records for all, my negatives. In my opinion, it is a high return on a small investment of time. A copy of my standard record-keeping form is supplied in the 'Tables and Templates' chapter, and fig.1 shows a filled-out sample. It is a modified version of an Ansel Adams proposal and has the benefit of keeping film and print records together on one sheet. I propose to file it with the negatives and proof sheets, having it at hand for later use.

## Exposure Records

The left-hand side of the form is used to record all relevant data about the film's exposure. On the top, the camera body and lens used for this exposure are entered. The filter section allows for marking the use of major contrast filters according to their Wratten numbers, neutral and graduated density filters, as well as some special filters. There is also room to record the negative number for roll film or the number of the negative holder, if sheet film is used.

The rectangle provides space to record light readings taken with a spotmeter. A simple line drawing of the scene suffices to record where shadow and highlight readings were taken. Once the negative is developed, a density reading will verify if film exposure and development are under control, or if they need modification. The Zone System bar is used to record the exposure value (EV) readings for significant shadow and highlight zones and to calculate the appropriate film development.

The film development and the target developer control the exposure index (EI) best suited for the film/developer combination used. This information is taken from a previously conducted film/developer test. See 'Customizing Film Speed and Development' for details. Several aperture/shutter combinations will fulfill the exposure requirement set by EI and EV. Select one from your lightmeter dial or consult your self-made 'Zone Dial', and enter the combination under ‘Basic Exposure’. Any exposure adjustments due to filter factors, bellows extensions or film reciprocity are filled in and totaled. I usually record them in stops, making it simpler to adjust the ‘Basic Exposure’ to the ‘Final Exposure’. Three icons allow recording of the lighting situation in form of daylight, flash or artificial light, respectively.

Recording all these steps in the field or on assignment is a time-consuming task, so I use a handheld voice recorder to quickly gather the information. After the scene is metered and the exposure is set on the camera, I just record all the data onto the tape. Looking at a sample of the form while recording avoids omitting any settings. At the end of the day, the tape is rewound and the data is transferred to the form without any need to rush. This is the least time-consuming operating procedure I have found, and it is an acceptable task considering the benefit of having all exposure data for future reference.

## Development and Printing Records

The right-hand side of the form is used to record all relevant data about film development and printing. Most of it is self-explanatory and requires little actual writing due to the multiple-choice layout. After film processing, all typical parameters are recorded under ‘Film Development’ and significant highlight and shadow densities are measured, if a densitometer is available. Enter the densities and calculate the difference between the two. This is the relative log exposure range of the negative and, consequently, the required paper contrast to print highlights and shadows equally well. If a densitometer is not available, rely on a darkroom meter or your experience for the initial paper contrast setting.

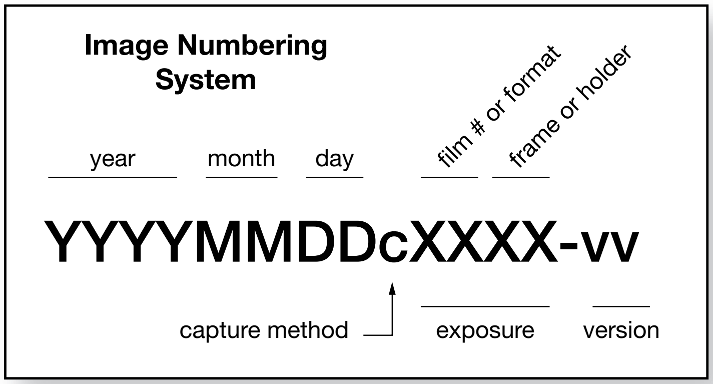


fig.2 The 15-digit image numbering system can keep thousands of negatives and digital image files organized. It is easy to locate the negative or digital file for a particular print, as long as the print is labeled with the corresponding image number.

Under ‘Print Development’, all parameters required to reproduce an identical print are entered. The multiple-choice section takes care of enlarger settings, including head tilt and lens shift/tilt for enlargers capable of ‘Scheimpflug’ adjustments. Enter the exposure time for the significant print highlights under ‘Base Time’, and record all print manipulations in stops, based on this time, in the printing map.

## Image Numbering System

In addition to maintaining clear printing records, it is equally important to have a consistent numbering system for our images. The 15-digit image numbering system in fig.2 keeps negatives and digital image files organized. I have used it to catalog my moderate library, which contains thousands of images and spans several decades. It has served me well, and there is never an issue in locating the negative or digital file for a particular print, as long as the print is labeled with the corresponding image number.

The image number starts with 8 digits to identify the year, month and day on which the image was taken. This is followed by a single letter for the method of image capture: ‘a’ for analog and ‘d’ for digital files. For analog files, the next 4 digits are used to identify the roll of film shot that day, and the specific negative frame on that roll. If I shot sheet film, the first 2 digits are used to point out the format (‘45’ for 4x5 sheet film) and the other two identify the film holder. For digital files, all 4 digits simply reflect the exposure counter of the digital camera, and I add 2 digits to distinguish different versions of image manipulation.

I hope that these examples of record keeping will help you maintain your own data and image files. Use the forms provided as is or customize them to your liking. Spending the extra effort will pay off big returns in the long run, and it will allow you to learn from your own experiences more quickly. It is satisfying to pick up a negative and start printing where you left off several months or years ago whenever you want to. However, do not use these records too rigidly. In order to improve, you have to deviate from previous exposures or print manipulations. Nevertheless, modifying previous settings, rather than starting from scratch, carries more educational value.

# Making Prints from Paper Negatives

## An old technique revisited with new materials

We expose and develop film solely to produce an intermediate film negative, which we subsequently contact print or enlarge to produce the final paper positive. This so-called negative/positive process was not how photography started, and when finally invented, early negatives were made from paper and not from film. Revisiting this old technique with modern materials creates very usable images of surprising quality.

The first successful photographs were produced in France during the 1820s by Joseph Nicephore Niépce, after he experimented for almost 30 years to create permanent images. By 1824, he had settled on a process for which a pewter plate is coated with a mixture of bitumen and lavender oil, a solution that hardens on lengthy exposure to light. The plate is placed inside a camera obscura and exposed for hours to capture

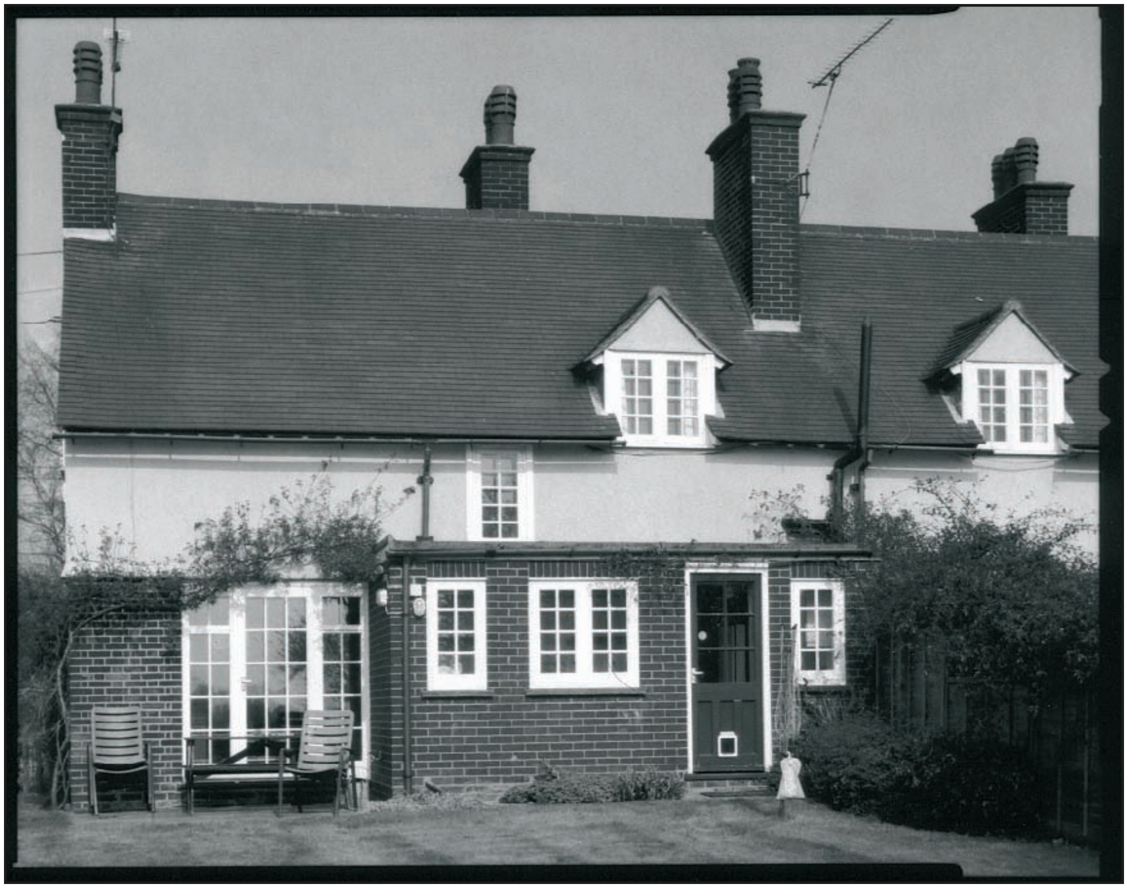


fig.1 Following in the footsteps of the inventors of photography, we can make B&W prints without film but from paper negatives, and, using modern resin-coated papers, these negatives are of surprising quality.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50081-8

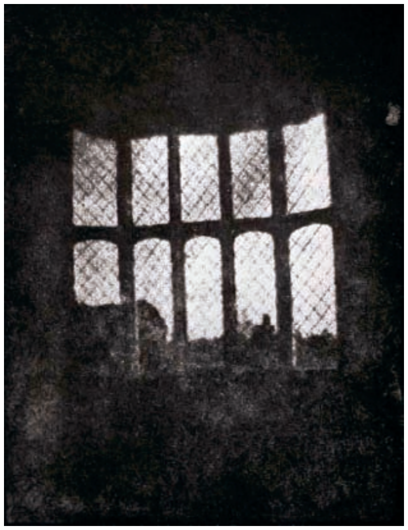
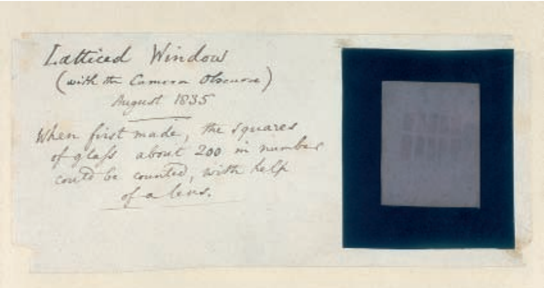


fig.2 This enlargement was made from the oldest camera negative in existence, taken by William Henry Fox Talbot in 1835. It shows a latticed window in the South Gallery of Lacock Abbey in Wiltshire, England and was taken from inside the abbey, which was Talbot's family home at the time. In his notes Talbot had written:

*Latticed Window*
*(with a Camera Obscura)*
*August 1835*
*When first made, the squares of*
*glass about 200 in number could*
*be counted, with help of a lens.*

© Reproduced from the National Museum of Photography, Film, and Television by courtesy of the Science and Society Picture Library.



Latticed Window
(with the Camera Obscura)
August 1835
When first made, the squares
of glass about 200 in number
could be counted, with help
of a lens.

the image. It is then removed, and any still soluble solution remaining in less exposed areas is washed out with pure lavender oil. Niépce called his process heliography, which literally means 'sun writing'. The oldest surviving photographs are heliographs made by Niépce in 1825 and 1826.

In 1829, Niépce agreed to form a business and development partnership with Louis J. M. Daguerre, but Niépce died only four years later. Daguerre, a painter and businessman without formal technical education, was forced to continue the experiments alone. By 1837, he had developed the fundamentals of a new and far more sophisticated method of creating permanent photographic images. The process involved coating a polished copper plate with light-sensitive silver iodine, and, subsequent to its exposure, developing it over poisonous mercury vapors. The resulting image was made stable by immersing the plate into a strong salt solution, followed by a wash. Daguerre's process produced a detailed one-of-a-kind picture of high quality, which he called Daguerreotype. He announced his results to the French Academy of Sciences on January 7th, 1839. After several failed attempts to market his invention, he managed to sell the patent rights to the French government in exchange for a life-long pension for himself and Niépce's widow. On August 19th, 1839, the French government declared the invention of photography a gift 'free to the world'.

For decades, several other individuals also tried to combine the camera obscura and chemistry to make permanent photographs. The most notable among them was William Henry Fox Talbot in England, who made successful photographs as early as 1833. After 1835, however, he made very little progress and eventually discontinued his developments. Due to many other interests, he also failed to make his invention public at the time. It was not until he heard rumors about Daguerre's invention that he hurriedly decided to prepare and present his paper to the Royal Society of London on January 25th, 1839, consequently missing Daguerre's presentation by only a few days. Talbot's invention, which he called Calotype, was not awarded a patent until 1841. His two-stage process required that a negative image be produced on light-sensitive paper first. The final positive image was then made on another sheet of light-sensitive paper by exposing it to light through the paper negative. Compared with Daguerreotypes, the quality of the early Calotypes was somewhat inferior. However, the great advantage of Talbot's invention was that an unlimited number of almost identical positives could be made at any time. In fact, today's photography is based on nearly the same principles, whereas the one-of-a-kind Daguerreotype turned out to be too limiting.

## Modern Materials and Equipment

Talbot's process is easily simulated with modern materials. The primary material properties for paper negatives are light sensitivity and translucency. Other requirements include good resolving power and flatness. The most-suitable modern material for paper negatives is resin-coated (RC) paper. They have an acceptable light sensitivity and are translucent enough for contact printing. Their resolving power is beyond human detection, and they stay reasonably flat inside the camera. Resin-coated papers, free of manufacturer logos, as in Ilford Multigrade IV-RC, can be used to prepare paper negatives of surprisingly high quality.

Any camera format will work, but since we are limited to contact printing, it is best to use the largest negative format possible. Large-format cameras are especially ideal. An old 11x14 or 8x10 view camera can be restored to make perfect paper negatives for contact printing. Also consider the use of large or medium-format pinhole cameras to create images of unique softness and beauty. Large-format benefits aside, don't let the exclusive availability of a 35mm camera stop you from walking in Talbot's footsteps. After all, the oldest paper negative in existence measures only about 1 inch square in size (fig.2). Revisiting this old technique is not just an interesting experiment in rediscovering the fundamentals of analog photography. It also returns surprisingly clear images of good tonality if used with modern materials and equipment.

## Exposing the Paper Negative

To ensure accurate paper-negative exposures in the camera, it is important to determine the effective paper speed. As with film, it is best to perform a customized test with the actual equipment and materials used. Doing so with my equipment and developing technique revealed a paper speed of EI 4 for Ilford Multigrade IV-RC. I suggest you test your favorite paper around this value in 1/3 or 1/2 stop increments. Find the speed that ensures adequate shadow detail in the paper negative, ignoring midtone and highlight areas. Fig.3a shows a typical result of such an initial test. The shadows have plenty of detail, but the highlights are far too dense to make a decent print from this paper negative. The reason is that modern photographic paper is not designed for this application. It is designed to create a positive image by reversing the tonality of a relatively low-contrast negative.

A 'normal' scene has a subject brightness range of 6 stops from the deep shadows of Zone II to the bright highlights of Zone VIII. This is not a problem with film negatives, which can handle exposure ranges of up to 15 stops or more, but it can be a problem with paper negatives. Exposed to unfiltered light, variable-contrast (VC) paper has an exposure range of only 3 1/2 stops, and if the exposure for a normal scene was metered for the shadows, as in fig.3a, then the highlights are doomed to block up. Nevertheless, with appropriate filtration, the exposure range can be significantly extended. Green (G11) and yellow (Y8) filters, typically used to enhance the contrast with film negatives, extend the paper exposure range to about 6 stops. I recommend the use of a yellow filter, because it requires less exposure correction to achieve a similar effect. Fig.3b shows how the use of a yellow filter and an exposure increase of 1 stop kept the shadow detail, while significantly reducing the highlight densities. This is a big improvement over the unfiltered exposure in fig.3a, and is all we can do during the exposure of the negative, but the resulting negative density range is still too wide to print the paper negative on grade-2 paper.

## Developing the Paper Negative

In regular B&W processing, the 6-stop subject brightness range of a normal scene is reduced to a negative density range of 3 1/2 stops during the development of the film in order to match the 3 1/2-stop exposure range of grade-2 paper. The filtered paper negative in fig.3b shows detail from shadows to highlights, but uses the entire paper density range of 7 stops to do so. This is far too much contrast to make a successful positive on normal-contrast paper.

With film negatives, contrast is controlled through development time. Too high of a negative contrast is avoided by reducing the development time; a lack

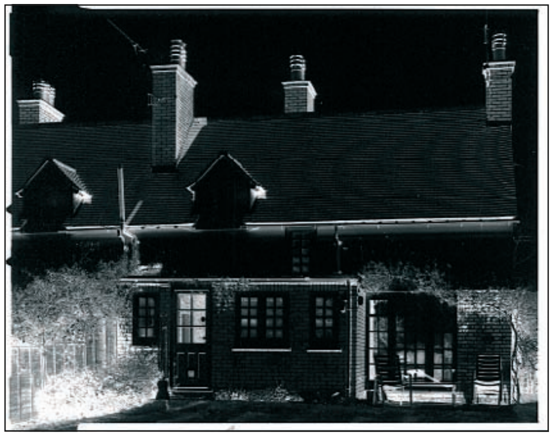


fig.3a *unfiltered exposure*
Exposing photographic paper in the camera, without filtration at EI 4, gives adequate shadow detail, but the highlights are far too dense to make a decent print. The subject brightness range is clearly beyond the capability of modern darkroom papers.

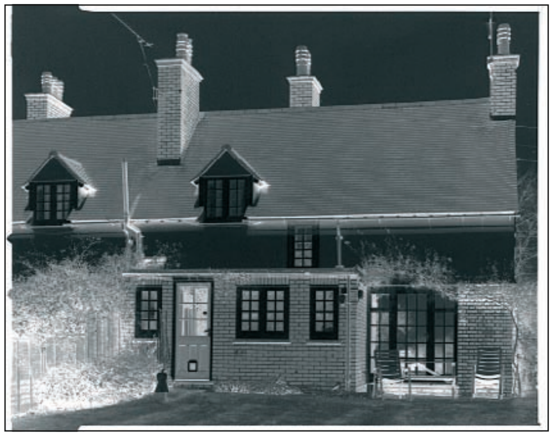


fig.3b *filtered exposure*
Using a yellow filter (Y8), and increasing the exposure by 1 stop, maintains the shadow detail, while significantly reducing the highlight densities. However, the paper negative density range is still too wide to fit on a grade-2 paper.

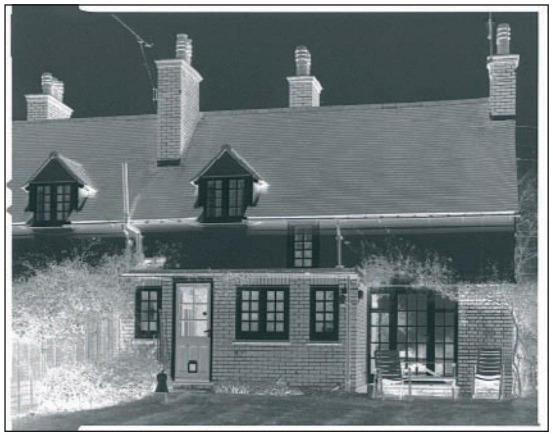


fig.3c *filtered exposure and weak development*
Exposing as in fig.3b, plus using a highly diluted paper developing solution, limits the highlight densities of the paper negative to manageable levels and secures shadow detail.

of contrast is compensated for by increasing the development time. Resin-coated (RC) paper, on the other hand, must be fully developed to avoid uneven development and ensure quality results. Consequently, reducing the development time is not an option to control the paper negative contrast.

However, one can reduce the developer concentration to successfully control paper negative contrast. My standard paper developer is Kodak Dektol, diluted with water to a 1+2 solution. The paper negative, shown in fig.3c, received the same filtered exposure as in fig.3b, but it was developed in a relatively weak 1+8 solution of Dektol for the entire standard duration of 90 seconds. The resulting negative has a 3 1/2-stop density range and prints well on a grade-2 paper.

## Printing the Paper Negative

Producing a print positive from a low-contrast paper negative is as simple as making a typical contact print. Without a negative in the carrier, the enlarger head is raised until it can be used to illuminate the entire baseboard. At this point, the enlarger only functions as a convenient light source, making it easy to control the exposure with a timer and the required paper contrast through already tested light-filtration values.

Place the printing paper into the middle of the baseboard, put the paper negative facedown on top of it and sandwich the assembly by covering both with a heavy sheet of glass. This brings the two emulsion sides firmly into direct contact with each other and makes for optimum print quality. The light from the enlarger will travel through the glass into the paper core of the negative, where it is totally diffused before it reaches the negative emulsion. The paper core should be as uniform as possible, and the back of the paper must be free of manufacturer's imprints. This is the case with the current Ilford Multigrade IV-RC.

Test for the optimum print exposure as you would for any other contact print, and adjust the paper contrast to utilize the entire paper negative density range. Do not hesitate to apply dodging and burning to further optimize print tones.

If you are willing to trade print quality for unusual effects, experiment with textured sheets, or simply turn the paper negative around. Using the paper thickness as a spacer, and diffusing the negative image through the paper core before it reaches the printing paper, leads to a softness that might suit certain images.

## Technical Background

Although knowledge of the underlying photographic principles is necessary for a full appreciation of this technique, no such knowledge is required to implement it, make interesting prints from paper negatives or just have fun with it. Consequently, some technical background is included for the more technical-minded photographers. Others, having a preference for image making over science, may skip this section and get their cameras ready.

The ability to get any paper grade from a single sheet of paper has made variable-contrast (VC) paper the prime choice for many photographers today. VC papers are coated with a mixture of separate emulsions, all of which are sensitive to blue light but vary in sensitivity to green light. Consequently, each component has a different spectral sensitivity, providing a different contrast. Blue light provides maximum contrast, and green light keeps contrast at a minimum. However, the paper is orthochromatic, insensitive to red light, which is why safelights work as well as they do. In so many words, variable-contrast papers are ideally suited for darkroom work. This changes when we use VC papers for in-camera exposures and turn them into paper negatives.

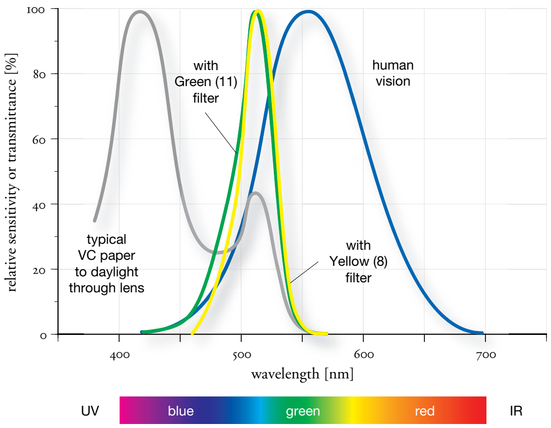


fig.4 Typical VC paper is over-sensitive to blue light when compared to the spectral sensitivity of human vision, resulting in a harsh high-contrast negative not suitable for pictorial work. A standard green or yellow filter easily corrects for this over-sensitivity and helps to create a paper negative of less contrast with a tonality similar to that of orthochromatic films.

Fig.4 shows how typical VC paper is over-sensitive to blue light when compared to the spectral sensitivity of human vision. During an average daylight exposure, all components of the paper emulsion react strongly to the UV radiation and blue light content. The reaction to green light is limited, and there is no reaction to red light. The result is a harsh high-contrast negative, which is not suitable for pictorial work (see fig.3a).

A standard green or yellow B&W contrast filter easily corrects for this over-sensitivity, which helps to create a paper negative with less contrast and a tonality similar to that of orthochromatic films. Fig.4 also illustrates how the effect of each filter is almost identical. Nevertheless, the yellow filter has the advantage of requiring only a 1-stop exposure correction, whereas the green filter needs 2 stops more light. The orthochromatic nature of photographic paper prevents a closer match to the spectral sensitivity of human vision, and for the same reason, paper negatives made from typical darkroom papers also have a tonality difference to panchromatic film.

At first, I was surprised by the excellent print quality achieved through paper negatives. The prints are typically sharp, clear and resolve fine detail beyond detection through the unaided eye. This becomes more understandable when we remind ourselves that standard human vision resolves 7 lp/mm, and critical observation senses detail up to 20 lp/mm. Normal printing paper, on the other hand, has a resolution limit of up to 60 lp/mm. This is not as good as film or 35mm lenses, but it is almost as good as most medium-format lenses and better than some large-format lenses. Since we are using our paper negatives only for contact printing, we are sure to get almost the entire optical potential of our lenses onto the paper, and that is more than our eyes can resolve.

© 2006 by Nicole Boenig-McGrade, all rights reserved

# Appendix

This page intentionally left blank

# Technical Fundamentals

## Numbering sequences, logarithms and some photo-mathematics

Photography is an art form. When people think about art, they think about self-expression, creativity and aesthetics, but not necessarily about craft and hard work. However, as Brett Weston so knowingly stated: "Photography is 90% sheer, brutal drudgery. The other 10% is inspiration." The brutal drudgery is the craft of photography; the knowledge of equipment and materials allows creativity to flow unhampered.

This book is about the craft of photography. It takes a balanced scientific approach, supported by many practical applications and examples. This combination, we hope, avoids misconception about conclusions and dispels unsubstantiated myths, of which there are many. This chapter refreshes the fundamental mathematical and optical concepts to explore the characteristics of film and paper.

### Arithmetic and Geometric Sequences

There are two types of numbering sequences common in camera and photographic work, arithmetic and geometric. The simplest number sequence is found on the exposure counter, where each number varies by one increment from its adjacent values (fig.1). This is called an arithmetic sequence, in this case, with an increment of 1. Sometimes, arithmetic sequences are called linear sequences, because they form a straight line when plotted on a graph.

Geometric sequences are also common in photography. The familiar lens-aperture, shutter-speed and film-sensitivity dials on a camera are examples of geometric sequences. Lens-aperture values (fig.2) form a geometric sequence with a factor equal to the square root of 2, approximated to 1.41. Each number is 1.41x more or less than its adjacent value, and it takes two steps to double or half the previous value. One might ask why the lens-aperture sequence has a factor of 1.41, when we know that each aperture setting doubles or halves the exposure. The aperture value is the focal length of the lens, divided by the diameter of the opening. The area of the opening, and hence the exposure, is proportional to the diameter squared. The area of each increasing aperture is, therefore, 1.41 squared or twice the size of the previous aperture value.

Shutter-speed markings (fig.3) are another example of a geometric sequence, because each number indicates half the exposure time of the previous setting. Some of the engraved markings are approximated to make the shutter-speed numbers easier to deal with. The film-sensitivity, or film-speed, values also form a geometric sequence with a factor of the cube root of 2, or approximately 1.26. In this sequence, it takes three steps to double or half the previous value.

### Lens Aperture, Shutter Speed and Film Sensitivity in Stops

Although the original definition for 'f/stop' referred to the lens aperture itself, the term 'stop' is commonly used to imply any doubling or halving of exposure. For instance, 'reduce the exposure by 2 stops' can mean either 'close the aperture by two f/stops' or 'set a shutter speed to 4x as fast'. Alternatively, one may choose to keep both exposure settings as is and reduce the film-speed by '2 stops'.

The term 'stop' is most useful when describing film and print exposures. However, when examining the material response to exposure, in order to evaluate film or print characteristics, it is more practical to work with reflection and transmission values, described in logarithmic density units.

### Logarithms

The elements controlling exposure all increase in geometric sequences. Therefore, the absolute values of exposure increase very quickly, leaving us with low and

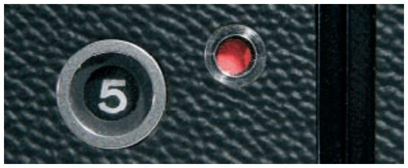


fig.1 The exposure counter is an example of an arithmetic numbering sequence.

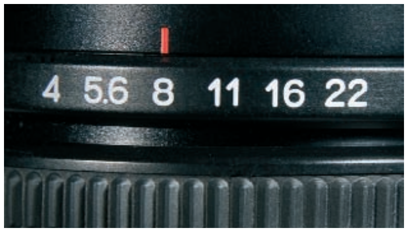


fig.2 The common progression of lens-aperture values, or f/stops, is an example of a geometric numbering sequence using a factor of 1.41.

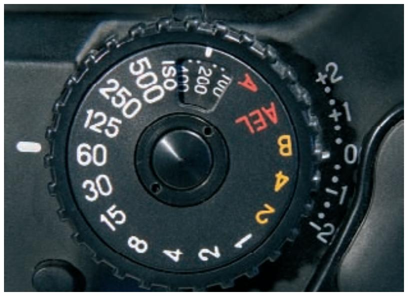


fig.3 The settings for shutter speed and film sensitivity (shown in the small dial window) are other examples of geometric numbering sequences.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50082-X

| film speed [ASA] | aperture [f/stop] | exposure time [1/s] |
|---|---|---|
| 3200 | 2.8 | 1 |
| ·<br>· | ·<br>· | ·<br>· |
| 1600 | 4 | 2 |
| ·<br>· | ·<br>· | ·<br>· |
| 800 | 5.6 | 4 |
| 640<br>500 | ·<br>· | ·<br>· |
| 400 | 8 | 8 |
| 320<br>250 | ·<br>· | ·<br>· |
| 200 | 11 | 15 |
| 160<br>125 | ·<br>· | ·<br>· |
| 100 | 16 | 30 |
| 80<br>64 | ·<br>· | ·<br>· |
| 50 | 22 | 60 |
| 40<br>32 | ·<br>· | ·<br>· |
| 25 | 32 | 125 |
| ·<br>· | ·<br>· | ·<br>· |
| 12 | 45 | 250 |
| ·<br>· | ·<br>· | ·<br>· |
| 6 | 64 | 500 |

fig.4 Rounded-off values for film speed, aperture and exposure times are incremented in stops, so when one is increased and another is decreased by the same factor, the total exposure remains constant.

high values of equivalent importance, but making low values hard to decipher. For this reason, we use logarithmic scales extensively in our graphs, in particular when describing the results from paper and film tests. These results often show print or negative density on the vertical axis of a graph and exposure along the horizontal, both plotted in logarithmic units.

It is not practical to use linear axes on these graphs, as it would make low-value interpretation difficult and limit their usefulness. For instance, the small horizontal difference between two closely spaced points (a&b) of low x-value may create the same vertical response as two other points (c&d) of higher x-value (fig.5). By comparison, the low-value information is easier to comprehend and quantify, when x-values are plotted in logarithmic units (fig.6).

The logarithm, or log, of a number is equal to the number of times by which the base value, most commonly '10', is multiplied by itself to produce that number. In mathematical terms, 10^(log(x)) = x. The numbers 10, 100 and 1000 have logs of 1, 2 and 3, respectively. Other numbers are more obscure, but easily found using a log table or scientific calculator.

For each stop up or down, the exposure doubles or halves, respectively, which is why it is important to remember two essential logs, log(2) = 0.3 and log(1/2) = -0.3. For each additional stop of exposure, the log exposure increases by 0.3. Therefore, a logarithmic exposure axis, marked in stops, will have markings at 0.3, 0.6, 0.9, 1.2 and so on.

If we take two numbers and add their logs together, the result is the same as multiplying the two numbers and taking their log. Similarly, if we wish to divide two numbers, a simple subtraction of their respective logarithms performs the division. For example, log(100/10) = log(100) - log(10).

For geometric sequences, working in logarithms makes the mathematics simpler. We know that three 1/3 stop increases in exposure equal 1 stop. Consequently, for each 1/3 stop increase in exposure, the log exposure increases by log(2)/3 or 0.1. This fact is the premise behind the once popular slide rule, which uses two sliding log scales to multiply or divide numbers by simply adding or subtracting distances along the scales. Logarithms are also used with photographic filters. A 3-stop neutral density filter may have any one of three exposure-compensation markings, as in +3, 8x or 0.9 marked on the rim, which are in stops, exposure ratio and transmission density, respectively.

Logarithms are commonly used to graphically display many photographic parameters. They are applied to exposure, light intensity, time or the optical density of a negative or print. For example, each doubling of exposure occupies an even 0.3 log unit along the horizontal axis of a graph, thereby converting a geometric number sequence into an arithmetic sequence.

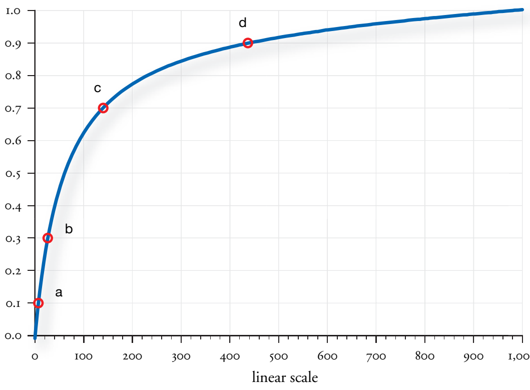


fig.5 In this example, sample curve data is charted using a linear scale for the vertical and horizontal axis. The first few hundred units of the horizontal axis contain most of the data, making a detailed interpretation in this area difficult and potentially inaccurate.

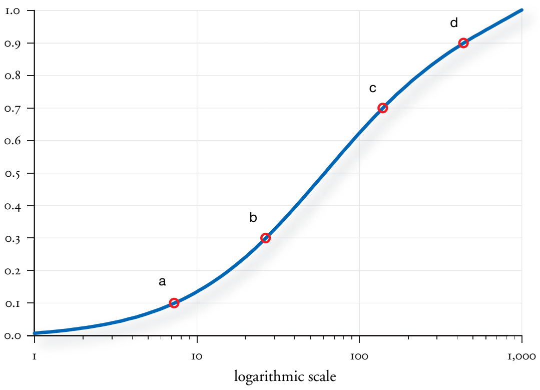


fig.6 In this graph, the same sample data as in fig.5 is charted, but this time, a logarithmic scale is used for the horizontal axis. The graph emphasizes the first hundred units of the horizontal axis, allowing for a more detailed and accurate interpretation in this area.

## Densities

Throughout this book, the terms reflection and transmission density are used to describe the appearance of prints and negatives. We can quantify how light or dark a certain area of the print is, by measuring the fraction of incident light reflected from its surface. Since the print surface never reflects or absorbs all of the light it receives, the reflectance value is always between 0 and 1. Reflection density is defined as the log of the reciprocal of reflection:

$$\textit{reflection density} = \log \frac{1}{\textit{reflection}}$$

Consider several examples. If the reflected light intensity equals the incident light intensity then the reflection density is log(1/1) = 0. The Kodak Gray Card has an 18% reflectance, which means for every 1 unit of light that falls upon its surface, 0.18 units are reflected. Its reflection density is, therefore, calculated as log(1/0.18) = 0.74. The above equation can also be solved for the actual reflection from a measured reflection density value (see equations in fig.7). For example, if the paper's white base (Dmin) has a density value of 0.05, then this paper reflects up to 89% of the incident light it receives (1/10^0.05 = 0.89), and if its maximum density (Dmax) measures 2.15, then it absorbs up to 99.3% (1/10^2.15 = 0.007) of the received light.

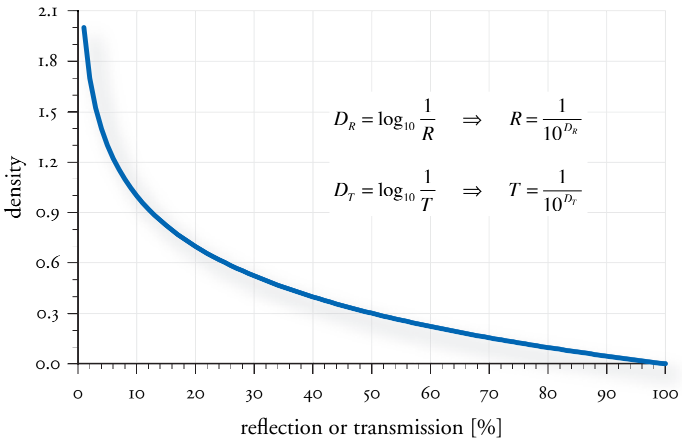
Since the print is the final stage of the photographic process, the appearance of the print is usually described in absolute terms of the 'absolute reflection density' or simply 'reflection density'. Therefore, two entirely different papers, with different base whites, will measure and look the same. In practice, a known reflection reference is placed under the densitometer and the display calibrated to the reference value. Densitometers that only have a zero reset button cannot measure absolute print densities and are limited to measure reflection densities relative to paper white. Densities measured with such a densitometer should be clearly labeled as 'relative reflection density'.

With a photographic negative, we are interested in the amount of light that passes through the film. We can quantify how dense highlights and shadows are by measuring the fraction of light transmitted through the negative. Transmission density is defined as the log of the reciprocal of transmission:

$$\textit{transmission density} = \log \frac{1}{\textit{transmission}}$$

A transmission densitometer is used to measure the transmission in log units. However, only the relative difference between shadow and highlight transmission densities is important, and so it is usually applicable to measure transmission relative to the clear negative material as 'relative transmission density' or just 'transmission density'. In practice, a piece of clear film is placed under the densitometer and the meter reset to '0'. In the exceptional case when absolute negative densities are measured, for instance to measure the effect of development fogging, the results should be clearly marked as 'absolute transmission density'.

The numbers representing lens apertures, shutter speeds and film sensitivity should become second nature to every photographer, but there is no need to do a lot of calculation to take good photographs. Nevertheless, it helps to be familiar with some of the terminologies of logs and densities, so one is able to interpret published or self-made film and paper characteristic curves, which contain a lot of useful information. Understanding a little bit more about the sometimes-complex techniques and processes of photography is not an absolute necessity, but it can be both rewarding and interesting at the same time.



| density | **light** transmitted by film or reflected by paper [%] |
|---|---|
| **0.0** | 100 |
| **0.3** | 50 |
| **0.6** | 25 |
| **0.9** | 13 |
| **1.2** | 6.3 |
| **1.5** | 3.1 |
| **1.8** | 1.6 |
| **2.1** | 0.8 |

fig.7 The percentage of incident light transmitted through a negative or reflected from a print can be expressed in density units. Every increase of 0.3 in density cuts light transmission or reflection in half.

# Make Your Own Transfer Function

## What you see is not always what you get

Typically, digital image manipulation is controlled and verified with the help of a calibrated monitor. It makes sense to manipulate individual image tones and overall contrast right on the screen, because a calibrated monitor provides reliable visual feedback immediately. However, this approach is of little value if the final print has little in common with what is shown on the screen. Ideally, we would like to have a perfect match between monitor and print tones (fig.1). This chapter shows why a perfect match is impossible, but how a well-designed transfer function produces a reasonably close match between monitor and print.

### Tone Reproduction

Image science differentiates between objective and subjective tone reproduction. Luminance is defined as the amount of light emitted or reflected from a surface. It can be objectively measured with a lightmeter. Brightness is defined as a subjective sensation produced by light, and it can only be approximated by psychological scaling procedures. Applying these terms to our task of creating a perfect match between monitor and print, the purpose of an objective tone reproduction is to create a print in which all monitor luminances are accurately reproduced. In other words, after the print is

THE OLD SHIP

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50083-1

made and properly illuminated, corresponding monitor and print measurements must return the same light readings. On the other hand, subjective tone reproduction is satisfied when it appears that monitor and print have the same brightness and overall contrast.

### The Impossible Match

Monitors and prints are fundamentally different in the way they produce an image. A monitor creates image detail and tonality through a matrix of pixels, emitting light at a number of different luminance levels. The print image, on the other hand, is made up of small, high and low-density areas, which reflect light at different levels of intensity.

The fact that a monitor emits light and a print reflects light is no reason that the two images cannot be matched. After all, in both cases light intensities can be measured as luminance values and compared to each other. Furthermore, print illumination can be altered until both values match. For example, you can easily measure the monitor luminance of a specific image area with a spotmeter and record the reading. If you then adjust the print illumination until the corresponding image area returns the same reading, both images have an identical luminance value for that area. Nevertheless, the two images only match if they also have the same overall contrast.

Modern monitors feature an image contrast of at least 400:1. Some provide a contrast of 800:1 or more, which is sufficient to realistically render outdoor scenes of the highest contrast. Silver-gelatin papers have a theoretical contrast range of up to 125:1, and inkjet papers go up to 250:1, but if we deduct the tonal extremes of their characteristic curves, their practical contrast limit is about 80:1. This is roughly half of what is needed to faithfully reproduce an average outdoor scene. The contrast difference between monitors and photographic papers is the main reason why it is not possible to obtain an accurate objective tone reproduction from monitor to print. As with slides in the past, monitors provide a more vibrant image experience than any printed media.

## The Rendering Intent

Fig.2 shows an example of a detailed subjective tone-reproduction study for a hypothetical imaging process. I am not suggesting that you conduct such a study just to make your own transfer function, because there is no need to do so, but fig.2 helps to understand how image tones are modified by the imaging process and how we can manipulate them to achieve a subjectively close match between monitor and final print.

A typical subjective tone-reproduction study is divided into four quadrants. Each quadrant (Q) represents one step of the reproduction cycle and illustrates the tonal modification during this step through a curve. In Q1, we see how digital image values are modified prior to image processing to achieve a close match between monitor and final print. Any undesired effect on image tonality by subsequent image processing is preempted through the curve in this quadrant. In other words, this quadrant is home to our transfer function, and we have full control over it, as we will see over the next few pages.

Q2 stands for the hypothetical process we have chosen to get the digital image onto paper. The curve in this quadrant is process dependent. It may represent the characteristics of a halftone negative, an inkjet printer or a more complex sequence of processing steps such as in the copy-print process. The details

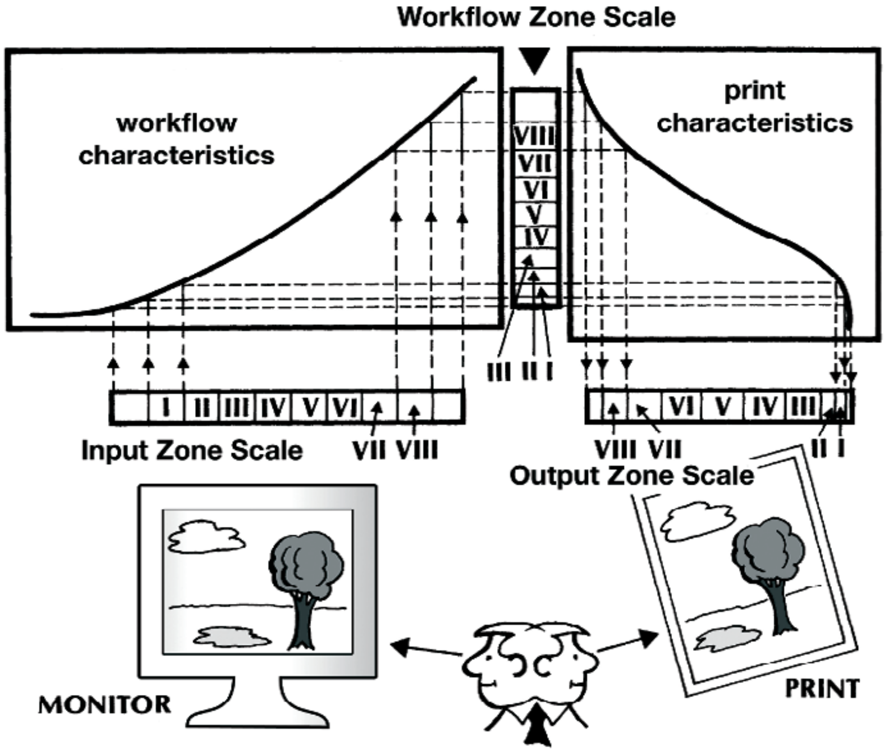
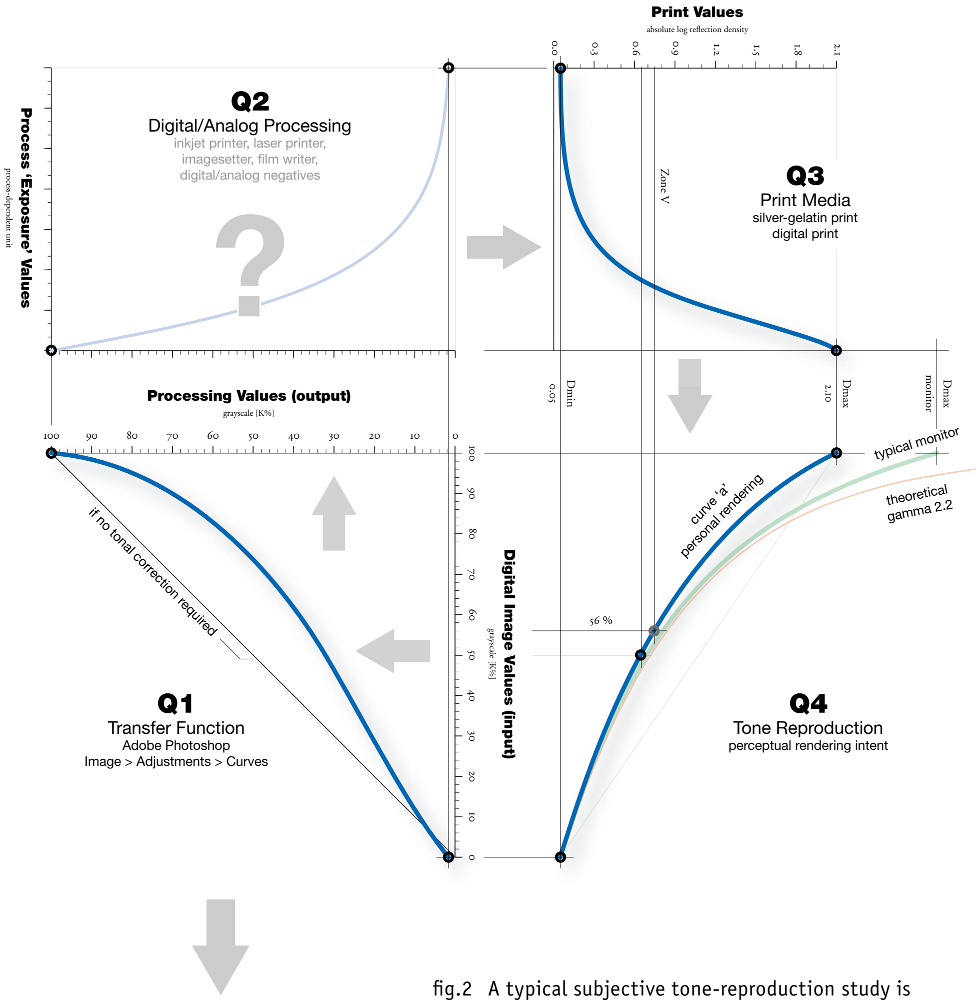
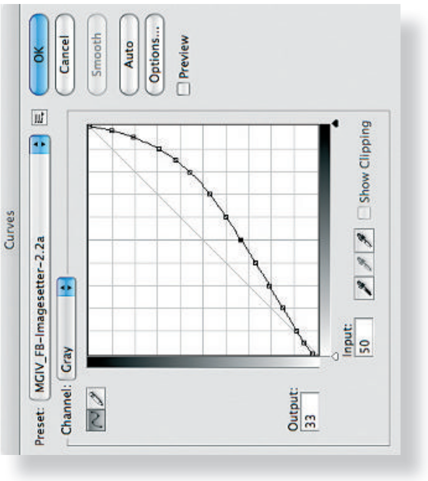


fig.1 The purpose of a transfer function is to bring the subjective tone-reproduction cycle full circle, and closely match the final print to the digital image seen on the computer monitor.

(based on an illustration by White, Zakia and Lorenz, *The New Zone System Manual*, Morgan & Morgan, Inc. ISBN 0-87100-100-4)





Preset: MGIV_FB-Imagesetter-2.2a

Channel: Gray

Input: 50

Output: 33

fig.2 A typical subjective tone-reproduction study is divided into four quadrants (top). Each quadrant (Q) stands for one step of the reproduction cycle. In Q1, digital image values are modified through a transfer function (left). Q2 stands for the process characteristics to get the digital image onto paper, which are not required to create a transfer function. Q3 illustrates how the chosen paper responds to the chosen process. Q4 shows the author's personal rendering intent (curve 'a') compared to typical monitor characteristics. To achieve a close contrast correlation between monitor and final print, highlight densities are overlaid and the curve is smoothly adjusted to account for the Dmax limitations of the print media. Midtone densities are maintained as much as possible. Once defined, this personal rendering curve can be used to create a transfer function for any digital/analog process, as long as the print media has the same Dmax.

of how image tones are processed and manipulated in this quadrant are of no concern to us and irrelevant for creating a transfer function. Nevertheless, this quadrant shows how the digital image data, corrected by the transfer function, is converted by our chosen process into 'exposure' of the print media. In this context, 'exposure' is used as a broad term, as it can refer to actual exposure of photographic paper through a negative, as well as to the amount of ink ejected by an inkjet printer to create density on inkjet paper.

Q3 shows the print media's characteristic curve. It illustrates how the chosen paper responds to the chosen process. The curve in this quadrant is material dependent, and as in Q2, we cannot alter this curve, but we can replace it with others by choosing a different print media. I have selected the curve of a paper with a maximum print density of 2.1, which is a typical Dmax value for photographic paper.

In Q4, we get the opportunity to define our personal rendering intent. We already discussed why a perfectly objective tone reproduction is not possible. The green 'typical monitor' curve verifies this point. A monitor, calibrated to gamma 2.2, emits a luminance difference of about 2.2 f/stops between image values of 0 and 50% gray (0-50K), which is exactly the theoretical value. Approaching image values of 100K, the monitor deviates significantly from theoretical gamma values. Nevertheless, the Dmax equivalents are still far beyond the paper's Dmax. The monitor image has more contrast than the print! To make up for this difference, and to create a print closely matching the on-screen image, we need to define what we feel is the most appropriate, subjective tone reproduction. We can do that by defining our personal rendering intent through a smooth curve.

Q4 shows the author's personal rendering intent (curve 'a') compared to typical monitor characteristics. To achieve a close contrast correlation between monitor and final print, highlight densities are overlaid and the curve is smoothly adjusted to account for the Dmax limitations of the print media, while midtone densities are maintained as much as possible. Once defined, this personal rendering curve can be used to create a transfer function for any digital/analog process, as long as the print media has the same Dmax. It is your perceptual rendering intent. To make it all work, we need to close the subjective tone-reproduction cycle in Q1 with a smooth transfer function.

## Creating the Transfer Function

The purpose of a transfer function is to bring the subjective tone-reproduction cycle full circle, and closely match the final print to the on-screen image. To do so, a transfer function must correct for the differences between the actual and the desired process characteristics. In order to design a transfer function, these differences must be clearly understood.

We already established our desired process characteristics with our personal rendering curve in Q4 of fig.2, which gives us a desired, absolute print reflection density for every on-screen value. These are listed as target densities in fig.4 for later use, and with the help of a step tablet, we are able to determine the actual characteristics of our chosen process.

A well-designed step tablet simplifies the development of a transfer function. The self-made example in fig.3 has a tonal spacing of 1% for the extreme highlight and shadow tones and a 2% spacing in the midtone area. It is available from our websites or can be constructed easily with any suitable drawing software.

Open the step tablet in your photo editing software, and run it through your process to bring it to paper. For example, if your process involves a digital halftone negative, send the file to a service bureau and have them produce such a negative of it. Once returned, produce a test print of that negative on your chosen photographic paper. Tone it, if that is part of your standard process, and check the actual densities for a few on-screen input percentage in the table of fig.4 with a densitometer. The measurements will most likely deviate from the target densities of your personal rendering intent. Now, find the patches on the test print that are closest in value to the desired target densities, interpolate if necessary, and list the actual percentages in the output column of fig.4.

The input and output values in fig.4 are entered into the 'Curves' adjustment dialog box of the photo editing software (fig.5) and saved as a transfer function for future use. From now on, this transfer function is applied to every digital image after final image manipulation, and just prior to committing it to the chosen process and the print media this transfer function was made for. This ensures that the final print will always be a close match to the on-screen image as seen on your monitor, even if process and paper changes, because all transfer functions designed this way are based on your personal rendering intent.

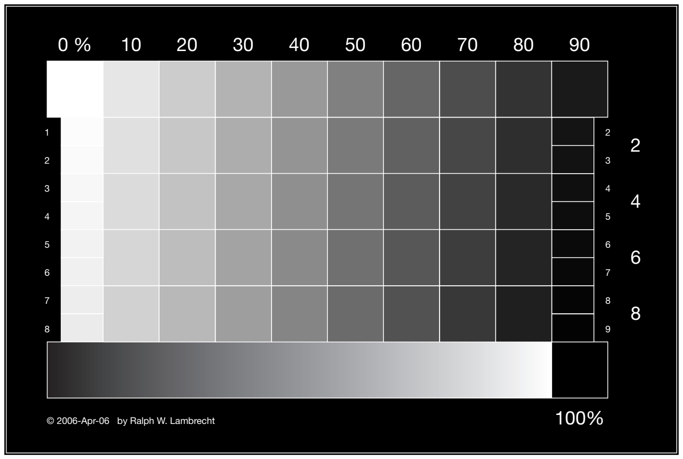


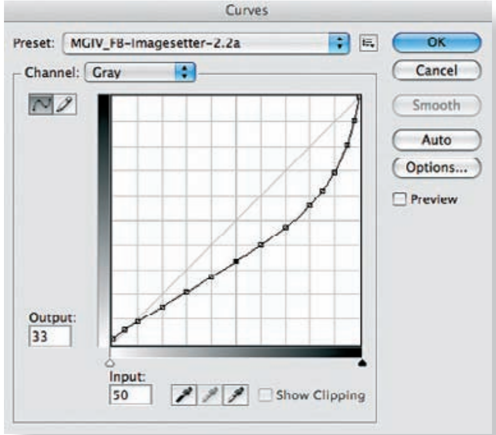
fig.3 (top) A well-designed step tablet simplifies the development of any transfer function. This self-made tablet has a tonal spacing of 1% for the extreme highlight and shadow tones and a 2% spacing in the midtone area. It is available from our websites or can be constructed easily with any suitable drawing software.

**Transfer Function Example**

(monitor γ = 2.2 > imagesetter > MGIV-FB)

| **Input** | **target density** | **Output** at |
|---|---|---|
| 0 % | 0.05 | 2 % |
| 5 % | 0.11 | 5 % |
| 10 % | 0.16 | 9 % |
| 20 % | 0.27 | 15 % |
| 30 % | 0.38 | 21 % |
| 40 % | 0.51 | 27 % |
| 50 % | 0.66 | 33 % |
| 60 % | 0.83 | 40 % |
| 70 % | 1.04 | 47 % |
| 80 % | 1.30 | 56 % |
| 85 % | 1.45 | 62 % |
| 90 % | 1.63 | 69 % |
| 95 % | 1.84 | 81 % |
| 98 % | 1.99 | 90 % |
| 100 % | 2.10 | 100 % |

fig.4 After running the step tablet in fig.3 through the chosen digital/analog process, the actual output values required to achieve the absolute target densities of our personal rendering intent are determined and listed against the digital, on-screen input values.


Curves

Preset: MGIV_FB-Imagesetter-2.2a

Channel: Gray

Output: 33

Input: 50

fig.5 The input and output values in fig.4 are entered into the 'Curves' adjustment dialog box of the Adobe Photoshop software and saved as a transfer function for future use. This transfer function is applied to every digital image after final image manipulation and just prior to committing it to the chosen digital/analog process and the print media this transfer function was made for.

# Photographic Chemistry

## An introduction for the non-chemist

Traditional photography combines art, technology and science, predominantly chemistry. From preparing light-sensitive emulsions to developing and creating permanent images, photographic chemistry is the backbone of traditional photography, controlling exposure, development and fixation.

During the exposure, light is directed onto the emulsion, where its radiation affects light-sensitive silver salts and produces a latent image. A chemical treatment, called development, turns the latent image into a visible image, by converting the silver salts that were affected by the exposure into metallic silver. All remaining silver salts, not affected by the exposure and, consequently, not changed by the developer, must subsequently be removed to produce a permanent image. This is accomplished through another chemical treatment, called fixing, which is followed by a final wash in plain water to remove chemical residue.

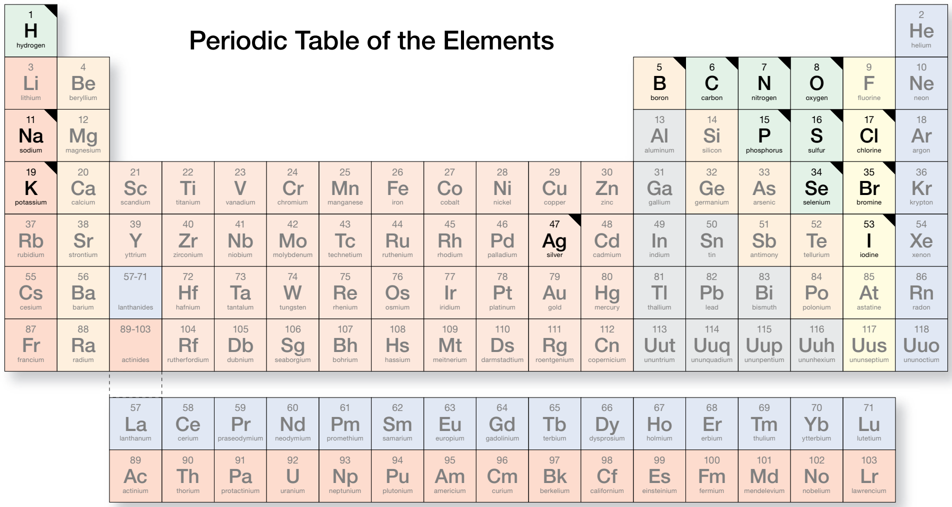


fig.1 As of this writing, in 2010, there are 118 elements known to exist, but only a few of them find significant use in silver-based photography.

A thorough understanding of chemistry is not required to effectively operate a darkroom. One can successfully process film and paper, using commercially available photographic chemistry, by simply following the instructions, without ever giving the underlying chemical processes much thought. However, preparing your own processing solutions according to a chemical formula, using raw chemicals, makes you independent of commercial product availability and provides the opportunity for customized process optimizations. In the following chapter, you will find a basic set of formulae for developers, a stop bath, fixers and other processing chemicals. To better understand the purpose and function of their main ingredients, it will be beneficial to have a rudimentary understanding of photographic chemistry.

### Elements and Compounds

For much of its history, chemistry was a relatively simple science with all matter divided into just four elementary materials: air, water, earth and fire. This changed in 1661 when Robert Boyle summarized a better understanding of matter and proposed that there is a difference between elements and compounds. Since then, an element is defined as the simplest form of matter (atom), indivisible and with individual characteristics, but, combined with each other, elements can create a number of compounds (molecules) with distinctively different properties. As of this writing, there are 118 known elements (fig.1), but only the first 94 elements occur naturally on earth. The rest are mainly short-lived by-products of nuclear reactions. The number of possible compounds, on the other hand, seems to be endless.

Compounds, created by chemical reaction, often have properties quite different from the elements they are made of. For example, the elements sodium and

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved
doi: 10.1016/B978-0-240-81625-8.50084-3

chlorine are both extremely dangerous, but when combined chemically, they produce harmless sodium chloride, which we know as ordinary table salt. The chemical equation for this reaction is written as:

$$\underset{\text{sodium}}{\text{Na}} + \underset{\text{chlorine}}{\text{Cl}} = \underset{\text{sodium chloride}}{\text{NaCl}}$$

## Types of Compounds

Elements can be roughly divided into two groups: metals and non-metals. Compounds can be classified as being organic or inorganic. Organic compounds are mainly composed of hydrogen, carbon, nitrogen, oxygen and sulfur. Inorganic compounds usually contain metallic elements. Another useful classification of compounds (fig.2) differentiates four groups:

**Oxides** are compounds of oxygen and other elements. Examples are sulfur dioxide ($S + O_2 = SO_2$) and sodium oxide ($4Na + O_2 = 2Na_2O$). Many oxides are soluble in water, and, depending on the type of element combined with the oxygen, this results in either an acid or a base.

**Acids** are formed when the oxides of non-metallic elements are dissolved in water. For example, sulfur dioxide dissolved in water produces sulfurous acid ($SO_2 + H_2O = H_2SO_3$). Acids are sour and have a pH value < 7.

**Bases** are formed when oxides of metallic elements are dissolved in water. For example, sodium oxide dissolved in water produces sodium hydroxide ($Na_2O + H_2O = 2NaOH$). Bases are alkaline and have a pH > 7.

**Salts** are typically combinations of acids and bases. For example, when sulfurous acid reacts with sodium hydroxide, sodium sulfite is formed ($H_2SO_3 + 2NaOH = Na_2SO_3 + 2H_2O$). Sodium sulfite is found in many photographic formulae.

## pH

The ‘power of hydrogen’, or pH, is a measure of strength for an acid or alkaline solution (fig.3), and measured pH values typically range from 1 to 14. Roughly speaking, the pH value is the negative logarithm of the hydrogen ion concentration, but it is more important to remember that acids have pH values < 7 and bases have pH values > 7. Distilled water is said to be neutral with a pH of 7.

Precise pH measurements require sophisticated pH meters, but sufficiently accurate pH values can be obtained with a litmus test. Litmus is a water-soluble dye that changes its color depending on the pH value of the solution with which it comes into contact. Test papers, containing litmus, turn bright red in acid solution and deep blue in alkaline solutions. The actual pH value can be estimated by comparing the resulting color to a calibrated color chart.

A pH test is useful for darkroom workers, because the pH value of a photographic solution is often an indicator of its freshness or activity. For example, a fresh acid stop bath has a pH value of 4 or less, but when in use, it will be continuously contaminated with alkaline developers. The alkali carry-over raises the pH value of the stop bath, and by the time it approaches a pH value of 6, the stop bath has lost most of its usefulness and must be replaced. In another example, the pH value of a developer can be an indicator of its activity. A changing pH value, due to age or usage, will lead to process inconsistencies, which can be predicted and controlled, after the actual pH value has been determined.

## Chemistry and Photography

In 1727, Johann Heinrich Schulze experimented with several compounds of silver and noticed that silver salts darkened under the influence of light. In 1802, Thomas Wedgwood and Humphrey Davy coated paper with a silver-salt solution and exposed it in a camera obscura to produce an image, which could only be seen for a limited time. In 1834, William Henry Fox Talbot suggested that a developer could amplify a weak exposure of silver salts, turning a latent image into a visible image, and in 1837, two years prior to the official invention of photography, John Herschel proposed sodium thiosulfate as a solvent for unexposed silver salts to create a permanent image.

## Emulsion

A photographic emulsion is a thin layer of light-sensitive material suspended in photography-grade gelatin. The gelatin makes it possible for the emulsion to be coated onto a substrate of glass, plastic film or paper. Three silver salts have been found to be particularly sensitive to light: *silver chloride* (AgCl), *silver bromide* (AgBr) and *silver iodide* (AgI), and as a group, they are often referred to as silver halides.

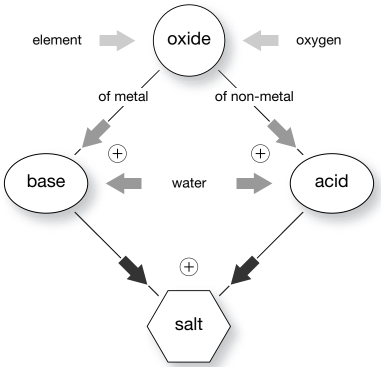


fig.2 Chemical compounds can be divided into oxides, acids, bases and salts.

| **pH** | |
|---|---|
| **14** | |
| **13** | |
| **12** | |
| **11** | *alkalinity* |
| **10** | |
| **9** | |
| **8** | |
| **7** | *neutral* |
| **6** | |
| **5** | |
| **4** | *acidity* |
| **3** | |
| **2** | |
| **1** | |

fig.3 The pH value is a measure of how strong an acid or alkaline solution is.

Typical emulsions contain a mixture of two or three silver halides, because they differ in light and color sensitivity. But, even as a group, they are mostly blue-sensitive and not able to record the entire visible spectrum. To make silver halides responsive to all wavelengths of light, complex organic chemicals, so-called optical sensitizers, are added to the emulsion. They act as an internal color filter, extending the color sensitivity from blue into green and red.

During the exposure, light energy is absorbed by the silver-halide crystals, which produces a chemical reaction within the salts. This creates a latent image, which is made visible through development.

## Developer

Developers are able to differentiate between exposed and unexposed silver halides. They liberate exposed silver halides from their salts and reduce them to metallic silver, but unexposed halides remain untouched. The chemical process of development is rather complex, and an exact equation cannot be given, but in simple terms, the following reaction takes place:

$$\begin{matrix}\mathrm{AgCl}\\\mathrm{AgBr}\\\mathrm{AgI}\end{matrix} > \text{exposure} > \text{development} = \mathrm{Ag}$$

Developer solutions contain a number of ingredients, which can be divided into four groups:

**Developing Agents** are relatively complex organic compounds, which provide the electrons required to reduce silver ions to metallic silver. The most commonly used developing agents are *metol*, *hydroquinone* and *phenidone*.

**Accelerators** increase the alkalinity of the developer and provide additional ions to create metallic silver. In general, the higher the pH value of the developer, the more active it is. Typical accelerators are *sodium hydroxide*, *sodium carbonate* and *borax*.

**Preservatives** are added to developer solutions to protect developing agents against oxidation. A frequently used preservative is *sodium sulfite*.

**Restrainers** suppress the formation of chemical fog, which is an unwanted silver production on unexposed silver halides. A minute amount of *potassium bromide* effectively reduces fog, but larger amounts affect the rate of normal development.

## Stop Bath

Once the desired degree of development has been reached, the process must be stopped quickly to avoid overdevelopment. This can be achieved through a simple water rinse, but an acid stop bath is more effective in neutralizing the alkaline activators and stopping development almost instantaneously.

A dilute solution of *acetic* or *citric acid* makes for a powerful stop bath. However, with developers containing *sodium carbonate*, the acid concentration must be kept sufficiently low to avoid the formation of carbon-dioxide gas bubbles in the emulsion, because this may lead to 'pinholes' in the emulsion.

## Fixer

After the stop bath has successfully terminated the development of exposed silver halides, all unexposed halides still remain in the emulsion, because they are not soluble in water. This is of great benefit during the development process, but during fixing, they must be removed completely, or they will eventually darken upon further exposure to light, and the image will not be permanent. This requires a fixing bath with a number of ingredients:

**Fixation Agents** must dissolve all remaining silver halides and convert them into water-soluble compounds. Only two chemicals, *sodium* and *ammonium thiosulfate,* are known to do that without negatively affecting the silver image or the gelatin layer. Since *ammonium thiosulfate* dissolves silver halides more rapidly than *sodium thiosulfate,* it is commonly known as 'rapid fixer'.

**Acids** are optional fixer ingredients, separating fixers into acid and alkali solutions. Acid fixers have the benefit of neutralizing any residual developer solution and preventing emulsion swelling in the wash. Often, a combination of *acetic* and *boric acid* is used. Acid-free fixers produce a less objectionable odor and are easier to wash out of the emulsion.

**Preservatives** are used with acid fixers to prevent an accumulation of sulfur, due to a reaction of thiosulfate with acids. This is achieved by adding *sodium sulfite*, which quickly reacts with colloidal sulfur and creates fresh sodium thiosulfate.

**Hardeners** can be added to prevent excessive swelling of the emulsion during washing and protect against physical damage. The most widely used

> I have never considered myself to be technical. To me, adding bromide or carbonate to a developer is about as technical as exposing for the shadows. Every photographer should know that!
>
> Steve Anchell

hardener is *potassium alum*. Hardeners impede washing and are not recommended for normal processing, but they find use in special application.

**Buffers** such as *sodium sulfite* and *sodium carbonate* are used to stabilize the pH value of acid and alkali fixers. If alkali fixers are preceded by an acid stop bath, *sodium carbonate* must be substituted with *sodium metaborate* or *balanced alkali* to avoid the formation of carbon-dioxide gas bubbles.

## Washing Aid

After fixing, emulsion and film or print substrate contain a considerable amount of thiosulfate, which must be removed so not to adversely affect later processing operations and to optimize image longevity. Washing is a combination of displacement and diffusion, and consequently not a chemical but a physical process. However, certain chemicals can positively affect the rate of washing and its efficiency.

According to *Modern Photographic Processing* by Grant Haist, a salt bath prior to washing was suggested as early as 1889, and washing in seawater has been known to speed up the rate of washing since 1903. On a global average, seawater contains roughly 3.5% salt, mainly sodium chloride. Unfortunately, seawater cannot be left in the emulsion, because the remaining salts cause a fading of the silver image under storage conditions of high humidity and temperature.

The modern alternative to seawater is a washing aid, containing up to 2% of *sodium sulfite*. Applying a washing-aid bath prior to the final wash is standard practice with fiber-base print processing, and is also recommended for film processing. It makes residual fixer and its by-products more soluble and reduces the washing time significantly. Washing aids are not to be confused with hypo eliminators, which are no longer recommended, since recent research has shown that minute amounts of thiosulfate actually protect the silver image against environmental attack.

An alternative to using *sodium sulfite* alone is using it together with *sodium bisulfite*, which is done in commercial washing aids. This constitutes a compromise, as lower pH values reduce emulsion swelling in the wash, but lowering the alkalinity also reduces the rate of thiosulfate elimination. To prevent calcium precipitation and 'print scum', some *sodium hexametaphosphate*, also known as *Photo Calgon*, may be added to the washing aid as a sequestering agent.

## Toner

Unprotected metallic image silver is subjected to constant attacks by reducing and oxidizing agents in our environment. The mechanisms of image protection are not entirely understood, but the positive influence of *sulfide* and *selenium* on silver image permanence is certain. Toning baths, containing *sodium sulfide, polysulfide* or *selenium*, convert the image forming metallic silver into more stable silver compounds, such as silver sulfide and silver selenide, and *sodium carbonate* buffers the pH value in polysulfide toners.

The information presented in this chapter was not designed to withstand scientific scrutiny. Instead, it was purposely oversimplified to provide a brief overview and basic understanding of chemistry and photographic processes, while trying to avoid getting hopelessly lost in scientific detail. I trust this will make some more comfortable with photographic chemistry and instigate others to deepen their studies. Much of what has been presented here can be found in far more detail in an excellent book, called *Photographic Chemistry* by George T. Eaton, which is unfortunately out of print. I highly recommend finding a secondhand copy of this book to anybody interested in the subject of photographic chemistry.

**A Note on Mixing Chemicals**

The sequence in which chemical compounds are listed in photographic formulae is not accidental. Always add them one after the other, according to the list.

a. weigh out dry chemicals onto separate pieces of small paper
b. arrange chemicals in order and add them one after the other
c. slowly sift chemicals into water while steadily stirring it
d. make sure it is completely dissolved before adding the next
e. always add acids to water and never the reverse, or spattering may cause serious injury
f. add alkali and acids slowly, as they may create intense heat when dissolved or diluted

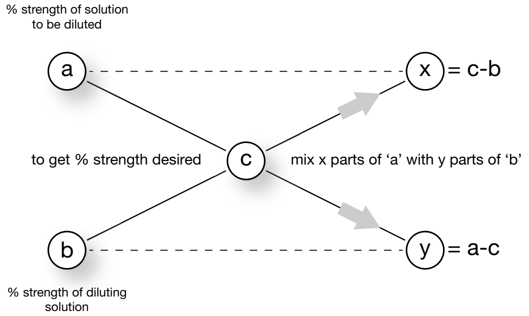

% strength of solution to be diluted
a
x
= c-b
to get % strength desired
c
mix x parts of 'a' with y parts of 'b'
b
y
= a-c
% strength of diluting solution

fig.4a The crisscross method is a simple technique of mixing two compatible liquids into a target solution of desired strength. It can be used to create a working solution from two existing stock solutions, or it may help to determine how a stock solution must be diluted to create the working solution.

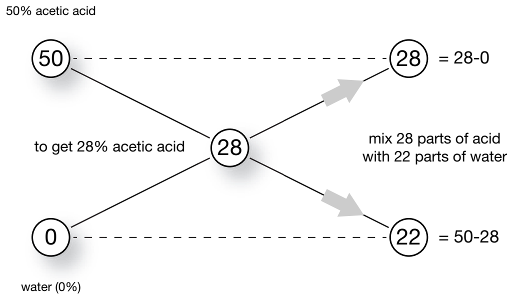


fig.4b In this example, 50% acetic acid is mixed with water (0%) at a ratio of 28/22 to create 28% acetic acid, by subtracting the working strength (c=28) from the stock strength (a=50) and the diluting strength (b=0) from the working strength (c=28) and knowing how many parts of each are required for the mixture.

# Basic Chemical Formulae

## The bare necessities of a life in the darkroom

**Typical Metric Units**

(use in photographic formulae)

1 kg = 1,000 g
1 g = 1,000 mg

1 l = 1,000 ml
1 ml = 20 drops

Among the plethora of developers, fixers and toners are an essential few, which will persevere through fashion and commercial profitability. The following is a complete set of basic formulae, which are essential for archival processing. We do not recommend to anyone to prepare their own chemistry as a means of 'saving money', but if you have a hard time obtaining darkroom supplies in your area, or if you like to modify proven formulae in order to obtain unique characteristics, the information presented is a good starting point. To see the whole gamut of darkroom alchemy with all its opportunities and alternatives, get yourself a copy of *The Darkroom Cookbook* by Steve Anchell and *The Film Developing Cookbook* by Anchell and Troop, and add them to your photographic library. These books contain an unrivalled collection of photographic formulae and easy-to-understand explanations on how to use them.

Many chemical suppliers do not sell directly to the public, but there are several suppliers of photographic chemicals around the world selling directly to photographers, including Silverprint in the UK, Artcraft Chemicals, Bostick & Sullivan and The Photographers Formulary in the USA. If you have difficulty finding a qualified local source, start by talking to your neighborhood drugstore or pharmacy. They will be able to either point you into the right direction or may actually sell you most of what you need.

**A Note on Safety**

As with all other chemicals, there are risks associated with contact, inhalation and ingestion of darkroom chemicals. We strongly advise that you study the material safety data sheet (MSDS) of each chemical before using it. In general, one must always observe the following practices while handling darkroom chemicals.

a. don't smoke in darkroom
b. don't eat or drink in darkroom
c. wear goggles
d. wear an apron
e. wear a face mask
f. wear rubber or latex gloves
g. ensure good ventilation
h. never inhale chemical dust
i. label chemical bottles clearly

**Equipment you need to get started:**

1. an old fashioned chemical balance or a modern electronic **scale**, accurate to at least ±0.1 grams and weighing up to 100 or 200 grams
2. plastic **syringes** of up to 1, 5 and 10 ml to accurately measure very small liquid volumes
3. a set of **graduated cylinders**, ranging from 30 ml to 1 liter for measuring liquids and solids
4. plastic **scoops** for measuring out chemicals
5. one to three plastic **beakers**, holding 1 and 2 liters each, for mixing working solutions
6. a small and a large plastic **stirring rod** to keep undissolved chemicals in motion
7. plastic **funnels** for pouring liquids into bottles
8. a selection of brown glass or plastic **bottles** to store the solutions and **labels** to identify them

**Initial Shopping List for Basic Chemicals**

| | |
|---|---|
| acetic acid *(28%)* | 500 ml |
| ammonium thiosulfate | 2 kg |
| borax *(sodium tetraborate, decahydrate)* | 500 g |
| boric acid *(granular)* | 250 g |
| citric acid | 100 g |
| hydroquinone | 250 g |
| metol | 100 g |
| phenidone | 25 g |
| potassium bromide | 100 g |
| potassium ferricyanide | 250 g |
| potassium iodide | 50 g |
| potassium permanganate | 10 g |
| potassium polysulfide *(liver of sulfur)* | 100 g |
| silver nitrate | 5 g |
| sodium carbonate *(monohydrate)* | 1 kg |
| sodium hexametaphosphate *(Photo Calgon)* | 100 g |
| sodium sulfite *(anhydrous)* | 2 kg |

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50085-5

## Film Developer (D-76 / ID-11)

D-76 is a fine-grain, general-purpose film developer for maximum shadow detail. It was formulated in 1926 by Kodak and still is the standard by which all other developers are judged, because it offers the best compromise between speed, sharpness and resolution. Many deviations from this original formula have been proposed over the years. A recent suggestion is to omit hydroquinone and raise metol to 2.5 g, creating D-76H, an environmentally friendly and more stable developer.

| | | |
|---|---|---|
| distilled water | *50°C / 120°F* | 750 ml |
| metol | | 2 g |
| sodium sulfite | *anhydrous* | 100 g |
| hydroquinone | | 5 g |
| borax | *decahydrate* | 2 g |
| cold distilled water to make | | 1,000 ml |

*dilute 1+1 for standard film development*
*use as one-shot developer for processing consistency*

## Neutral Paper Developer (D-72)

D-72 is a neutral-tone paper developer for brilliant highlights and maximum blacks, very similar to Kodak Dektol. Standard dilution for this developer is 1+2, but it can be diluted 1+1 for a longer shelf life and slightly higher Dmax, or 1+3 for warmer tones and softer shadows. It has excellent keeping properties and an outstanding development capacity. Replace with fresh developer as soon as factorial development fails to create potential Dmax.

| | | |
|---|---|---|
| water | *50°C / 120°F* | 750 ml |
| metol | | 3 g |
| sodium sulfite | *anhydrous* | 45 g |
| hydroquinone | | 12 g |
| sodium carbonate | *monohydrate* | 80 g |
| potassium bromide | | 2 g |
| cold water to make | | 1,000 ml |

*dilute 1+2 for standard paper development*
*very similar to Kodak Dektol*

## Warm-Tone Paper Developer (ID-78)

ID-78 is a warm-tone paper developer with a formulation very close to Ilford Warmtone and Agfa Neutol WA. It works well with all modern neutral and warm-tone papers on the market. Dissolve the phenidone separately in 50 ml of hot water (>80°C). Standard dilution for this developer is 1+3, but it can be used as strong as 1+1 for richer shadows. Replace with fresh developer as soon as factorial development fails to create potential Dmax.

| | | |
|---|---|---|
| water | *50°C / 120°F* | 750 ml |
| sodium sulfite | *anhydrous* | 50 g |
| hydroquinone | | 12 g |
| phenidone | | 0.5 g |
| sodium carbonate | *monohydrate* | 72 g |
| potassium bromide | | 4.5 g |
| cold water to make | | 1,000 ml |

*dilute 1+3 for warm-tone paper development*
*very similar to Ilford Warmtone and Agfa Neutal WA*

## Stop Bath (SB-7)

SB-7 is an odorless acid stop bath for film and paper processing. It quickly neutralizes the alkaline developer and brings development to a complete stop. Its capacity is approximately ten rolls of film or 8x10-inch prints per liter. Use prior to acid fixers, and precede alkaline fixers with a plain water rinse instead.

| | |
|---|---|
| water | 750 ml |
| citric acid | 15 g |
| water to make | 1,000 ml |

*working solution for paper, dilute 1+1 for film*

## Acid Rapid Fixer (RF-1)

| | |
|---|---|
| water *50°C / 120°F* | 750 ml |
| ammonium thiosulfate | 120 g |
| sodium sulfite *anhydrous* | 12 g |
| acetic acid *28%* | 32 ml |
| boric acid *granular* | 7.5 g |
| cold water to make | 1,000 ml |

*working solution for film and paper*
*use two-bath fixing method for film and fiber-base paper*
*with film, use as one-shot fixer for processing consistency*

RF-1 is a non-hardening, acid, rapid fixer for film and paper. The omission of a hardener supports archival washing and makes it easier for spotting fluids to be absorbed by the print emulsion. Dissolve the boric acid separately in 80 ml of hot water (>80°C) and add last, or substitute with 9 g of sodium carbonate to create an almost odorless version of this fixer. We recommend using the two-bath fixing method for film and fiber-base paper, both at full fixer strength. The first fixing-bath capacity is approximately ten 8x10-inch prints per liter.

## Alkaline Rapid Fixer (RF-2)

| | |
|---|---|
| water *50°C / 120°F* | 750 ml |
| ammonium thiosulfate | 120 g |
| sodium sulfite *anhydrous* | 15 g |
| sodium carbonate *monohydrate* | 0.7 g |
| cold water to make | 1,000 ml |

*working solution for film and paper*
*use two-bath fixing method for film and fiber-base paper*
*with film, use as one-shot fixer for processing consistency*

RF-2 is a non-hardening, alkaline, rapid fixer for film and paper, supporting an odorless darkroom environment and significantly reducing washing times. To conduct an entirely acid-free process, do not use in combination with an acid stop bath. Instead, follow development by a 60s wash in plain water, and use the two-bath fixing method for film and fiber-base paper at full fixer strength. The first fixing-bath capacity is approximately ten 8x10-inch prints per liter.

## Hypo-Clearing Agent (HCA-1)

| | |
|---|---|
| water *50°C / 120°F* | 750 ml |
| sodium sulfite *anhydrous* | 100 g |
| sodium hexametaphosphate * | 5 g |
| cold water to make | 1,000 ml |

*dilute 1+4 for film or paper*
** add with hard water supplies to prevent calcium scum*

HCA-1 is a washing aid for film and paper, used subsequent to acid fixers. Treat films for 2 and papers for 10 minutes with slight agitation. Used after a preceding water rinse, the capacity is approximately twenty rolls of film or 8x10-inch prints per liter. With hard water supplies, add sodium hexametaphosphate (Photo Calgon) to prevent the formation of calcium scum on the emulsion surface.

## Polysulfide Toner (T-8)

| | |
|---|---|
| water | 750 ml |
| potassium polysulfide | 7.5 g |
| sodium carbonate *monohydrate* | 2.5 g |
| water to make | 1,000 ml |

*working solution for direct paper toning*

T-8 is a direct polysulfide toner for modern papers, similar to Kodak Brown Toner or Agfa Viradon, and can be used at room temperature. Wash fiber-base prints for 30 minutes without washing aid prior to toning. Please note that this toner produces toxic hydrogen sulfide gas, as well as the offensive odor that goes along with it. Only use with adequate ventilation.

At this dilution, R-4 is a proportional reducer for film and paper. Apply with a brush to locally improve print highlights, or treat an entire film to reduce overall negative density. Use solutions in sequence or mix 1+1 just prior to use. Solution A will last for months, but if combined with solution B, the mixture will deteriorate within 10 minutes. Rinse film or paper thoroughly after use. Then, fix again and continue with normal processing.

## Farmer's Reducer (R-4)

**Solution A**

| | |
|---|---|
| potassium ferricyanide | 10 g |
| water to make | 1,000 ml |

**Solution B**

| | |
|---|---|
| rapid fixer *working solution* | 1,000 ml |

*use solutions in sequence or mix 1+1 just prior to use*

FT-1 is a fixer test solution when archival processing is not required. Add 1 ml to 10 ml of used fixer and stir, and discard the fixing bath if a cloudy, white precipitate forms in the mixture. For archival processing requirements, measure the silver content of the fixing bath with a professional silver estimator.

## Fixer Test Solution (FT-1)

| | |
|---|---|
| water | 80 ml |
| potassium iodide | 5 g |
| water to make | 100 ml |

*add 1 ml to 10 ml of used fixer*

HT-1 is a residual hypo test to verify the efficiency of film washing. 1 ml of the test solution is applied to 10 ml of the film's last wash water. The resulting color change of the wash water depends on its thiosulfate content and becomes a rough measure of the emulsion's residual thiosulfate level.

## Residual Hypo Test (HT-1)

| | |
|---|---|
| distilled water | 80 ml |
| potassium permanganate | 0.1 g |
| sodium carbonate *monohydrate* | 0.2 g |
| distilled water to make | 100 ml |

*add 1 ml to 10 ml of the film's last wash water*

HT-2 is a residual hypo test to verify the efficiency of print washing. The color stain left by the test solution is an indicator of the hypo level in the paper. HT2 contains light sensitive silver nitrate. Consequently, the entire test must be conducted under subdued tungsten light. Please note that silver nitrate requires 24 hours to completely dissolve.

## Residual Hypo Test (HT-2)

| | |
|---|---|
| water | 80 ml |
| acetic acid *28%* | 12 ml |
| silver nitrate | 0.8 g |
| water to make | 100 ml |

*apply a drop to a damp print border for 5 minutes*

# Tables and Templates

## A collection of useful look-up and conversion tables, and some templates to support your work

© 2008 by Thomas Bertilsson, all rights reserved

A considerable amount of scientific work and care has gone into the preparation of this book. All authors made an effort to take nothing for granted and challenged many photographic myths. To prove out these challenges, numerous tests were conducted, evaluated and archived. However, some material and processing conditions and their combinations are either not predictable, or depend entirely on the individual setup and material choices. Consequently, you may wish to conduct your own tests, which allows for individual calibration and provides you with confidence and knowledge about your own materials and techniques. Testing should be kept to a minimum; after all, the main purpose of our efforts is to create beautiful images and get them ready for display. Nevertheless, a few basic tests save time, material and frustration in the long run, while improving and assuring quality results and making our photography more enjoyable.

The tables and templates in this chapter are prepared to help you run a few experiments using your own photographic papers and films. Feel free to copy the individual pages from the book for your own test records and evaluations, but take care not to damage the book. Some templates are used as overlays and must be the same scale as the data sheets evaluated. If possible, copy overlays onto transparent material. Otherwise, use them in combination with the data sheets on a light table or against a window.

To obtain accurate and repeatable results, many tests rely on the availability of a reflection and transmission densitometer. We realize that such an instrument is a serious investment for any photographer, but its many uses will soon justify the purchase. Densitometers are often available from a friend or on the secondhand market. If all else fails, every 1-hour photo-lab has one to calibrate their systems, and the owner may be willing to take a few readings for you.

© 2011 Ralph W. Lambrecht and Chris Woodhouse. Published by Elsevier Inc. All rights reserved

doi: 10.1016/B978-0-240-81625-8.50086-7

## Standard Values for Negatives, Prints and Monitors

| Zone | Negative | Print | Monitor |
|---|---|---|---|
| **0** | **0.00** | **2.10** | **100%** |
| • | 0.03 | 2.09 | |
| •• | 0.07 | 2.06 | |
| **I** | **0.10** | **2.04** | **99** |
| • | 0.14 | 2.00 | 98 |
| •• | 0.19 | 1.95 | 97 |
| **II** | **0.24** | **1.89** | **96** |
| • | 0.28 | 1.81 | 95 |
| •• | 0.33 | 1.72 | 93 |
| **III** | **0.38** | **1.61** | **90** |
| • | 0.43 | 1.48 | 86 |
| •• | 0.49 | 1.34 | 82 |
| **IV** | **0.54** | **1.19** | **77** |
| • | 0.60 | 1.04 | 71 |
| •• | 0.66 | 0.89 | 64 |
| **V** | **0.72** | **0.75** | **56** |
| • | 0.78 | 0.62 | 48 |
| •• | 0.84 | 0.50 | 40 |
| **VI** | **0.90** | **0.40** | **32** |
| • | 0.97 | 0.32 | 25 |
| •• | 1.03 | 0.25 | 19 |
| **VII** | **1.10** | **0.19** | **14** |
| • | 1.16 | 0.15 | 10 |
| •• | 1.22 | 0.12 | 6 |
| **VIII** | **1.29** | **0.09** | **4** |
| • | 1.35 | 0.08 | 3 |
| •• | 1.42 | 0.07 | 2 |
| **IX** | **1.48** | **0.06** | **1** |
| • | 1.55 | 0.05 | 0 |
| •• | 1.61 | | |
| **X** | **1.67** | | |
| • | 1.73 | | |
| •• | 1.79 | | |
| **XI** | **1.85** | | |

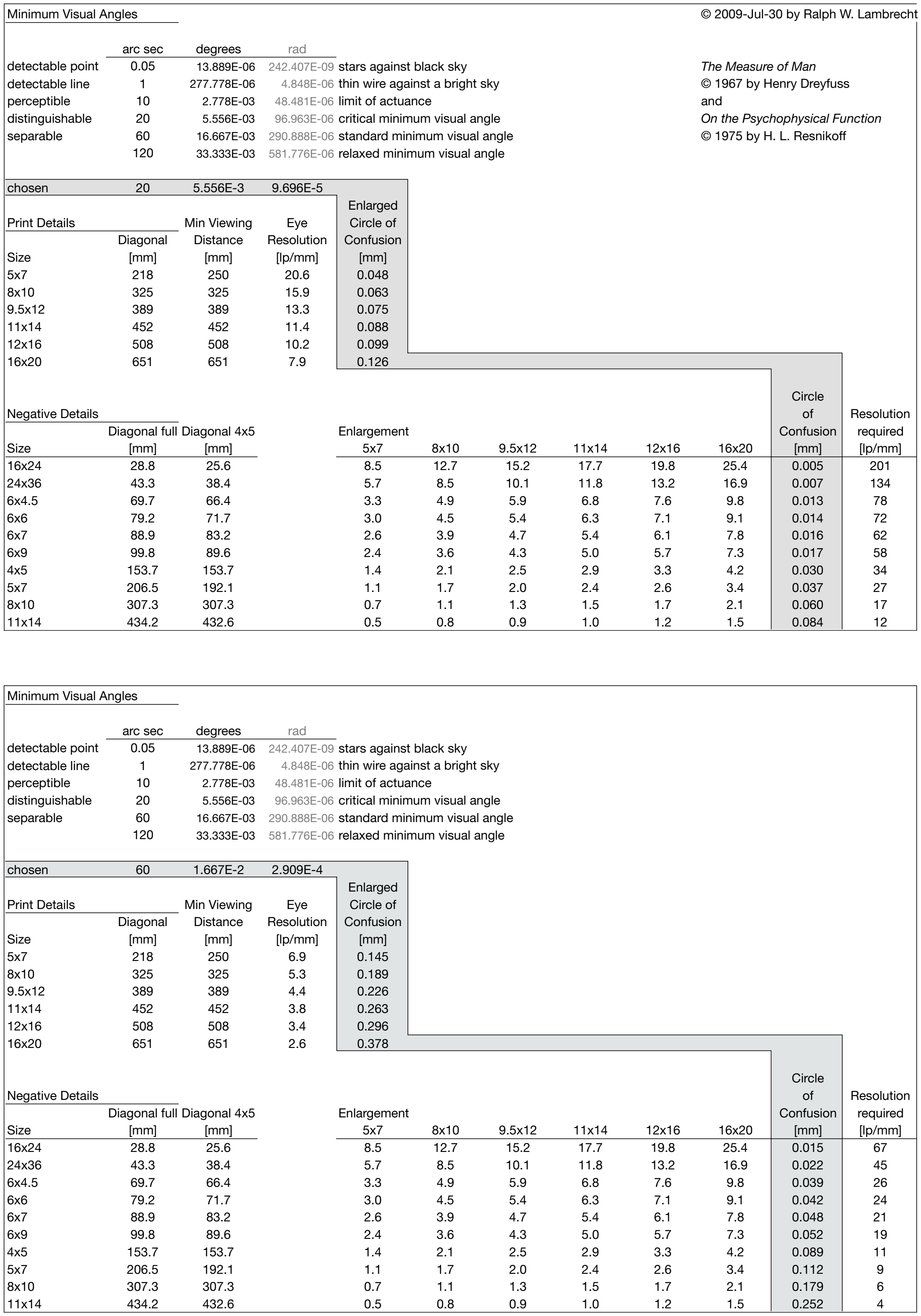
fig.1 Standard, normal development, Zone System density values for relative negative transmission and absolute print reflection, as well as digitally representative grayscale values for computer monitors set to 2.2 gamma, are shown in 1/3-stop increments.

# f/stop Timing Table [s]

| dodging [f/stop] ← | | | | | | base exposure | → burning [f/stop] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **-1** | -⅚ | **-⅔** | -½ | **-⅓** | -⅙ | | +⅙ | **+⅓** | +½ | **+⅔** | +⅚ | **+1** | +1 ⅓ | +1 ⅔ | **+2** | +2 ⅓ | +2 ⅔ | **+3** |
| **-4.0** | -3.5 | **-3.0** | -2.3 | **-1.7** | -0.9 | **8** | 1.0 | **2.1** | 3.3 | **4.7** | 6.3 | **8.0** | 12.2 | 17.4 | **24.0** | 32.3 | 42.8 | **56.0** |
| -4.2 | -3.7 | -3.1 | -2.5 | -1.7 | -0.9 | 8.5 | 1.0 | 2.2 | 3.5 | 5.0 | 6.6 | 8.5 | 12.9 | 18.4 | 25.4 | 34.2 | 45.3 | 59.3 |
| -4.5 | -3.9 | -3.3 | -2.6 | -1.9 | -1.0 | 9.0 | 1.1 | 2.3 | 3.7 | 5.3 | 7.0 | 9.0 | 13.6 | 19.5 | 26.9 | 36.3 | 48.0 | 62.9 |
| -4.8 | -4.2 | -3.5 | -2.8 | -2.0 | -1.0 | 9.5 | 1.2 | 2.5 | 3.9 | 5.6 | 7.4 | 9.5 | 14.5 | 20.7 | 28.5 | 38.4 | 50.9 | 66.6 |
| **-5.0** | -4.4 | **-3.7** | -3.0 | **-2.1** | -1.1 | **10.1** | 1.2 | **2.6** | 4.2 | **5.9** | 7.9 | **10.1** | 15.3 | 21.9 | **30.2** | 40.7 | 53.9 | **70.6** |
| -5.3 | -4.7 | -4.0 | -3.1 | -2.2 | -1.2 | 10.7 | 1.3 | 2.8 | 4.4 | 6.3 | 8.3 | 10.7 | 16.2 | 23.2 | 32.0 | 43.1 | 57.1 | 74.8 |
| -5.7 | -5.0 | -4.2 | -3.3 | -2.3 | -1.2 | 11.3 | 1.4 | 2.9 | 4.7 | 6.6 | 8.8 | 11.3 | 17.2 | 24.6 | 33.9 | 45.7 | 60.5 | 79.2 |
| -6.0 | -5.3 | -4.4 | -3.5 | -2.5 | -1.3 | 12.0 | 1.5 | 3.1 | 5.0 | 7.0 | 9.4 | 12.0 | 18.2 | 26.1 | 36.0 | 48.4 | 64.1 | 83.9 |
| **-6.3** | -5.6 | **-4.7** | -3.7 | **-2.6** | -1.4 | **12.7** | 1.6 | **3.3** | 5.3 | **7.5** | 9.9 | **12.7** | 19.3 | 27.6 | **38.1** | 51.3 | 67.9 | **88.9** |
| -6.7 | -5.9 | -5.0 | -3.9 | -2.8 | -1.5 | 13.5 | 1.6 | 3.5 | 5.6 | 7.9 | 10.5 | 13.5 | 20.4 | 29.3 | 40.4 | 54.4 | 72.0 | 94.2 |
| -7.1 | -6.3 | -5.3 | -4.2 | -2.9 | -1.6 | 14.3 | 1.7 | 3.7 | 5.9 | 8.4 | 11.1 | 14.3 | 21.7 | 31.0 | 42.8 | 57.6 | 76.3 | 99.8 |
| -7.6 | -6.6 | -5.6 | -4.4 | -3.1 | -1.6 | 15.1 | 1.8 | 3.9 | 6.3 | 8.9 | 11.8 | 15.1 | 23.0 | 32.8 | 45.3 | 61.0 | 80.8 | 106 |
| **-8.0** | -7.0 | **-5.9** | -4.7 | **-3.3** | -1.7 | **16** | 2.0 | **4.2** | 6.6 | **9.4** | 12.5 | **16.0** | 24.3 | 34.8 | **48.0** | 64.6 | 85.6 | **112** |
| -8.5 | -7.4 | -6.3 | -5.0 | -3.5 | -1.8 | 17.0 | 2.1 | 4.4 | 7.0 | 10.0 | 13.3 | 17.0 | 25.8 | 36.9 | 50.9 | 68.5 | 90.7 | 119 |
| -9.0 | -7.9 | -6.6 | -5.3 | -3.7 | -2.0 | 18.0 | 2.2 | 4.7 | 7.4 | 10.5 | 14.0 | 18.0 | 27.3 | 39.1 | 53.9 | 72.6 | 96.1 | 126 |
| -9.5 | -8.3 | -7.0 | -5.6 | -3.9 | -2.1 | 19.0 | 2.3 | 4.9 | 7.9 | 11.2 | 14.9 | 19.0 | 28.9 | 41.4 | 57.1 | 76.9 | 102 | 133 |
| **-10.1** | -8.8 | **-7.5** | -5.9 | **-4.2** | -2.2 | **20.2** | 2.5 | **5.2** | 8.4 | **11.8** | 15.8 | **20.2** | 30.6 | 43.8 | **60.5** | 81.4 | 108 | **141** |
| -10.7 | -9.4 | -7.9 | -6.3 | -4.4 | -2.3 | 21.4 | 2.6 | 5.6 | 8.8 | 12.5 | 16.7 | 21.4 | 32.5 | 46.4 | 64.1 | 86.3 | 114 | 150 |
| -11.3 | -9.9 | -8.4 | -6.6 | -4.7 | -2.5 | 22.6 | 2.8 | 5.9 | 9.4 | 13.3 | 17.7 | 22.6 | 34.4 | 49.2 | 67.9 | 91.4 | 121 | 158 |
| -12.0 | -10.5 | -8.9 | -7.0 | -4.9 | -2.6 | 24.0 | 2.9 | 6.2 | 9.9 | 14.1 | 18.7 | 24.0 | 36.4 | 52.1 | 71.9 | 96.8 | 128 | 168 |
| **-12.7** | -11.1 | **-9.4** | -7.4 | **-5.2** | -2.8 | **25.4** | 3.1 | **6.6** | 10.5 | **14.9** | 19.9 | **25.4** | 38.6 | 55.2 | **76.2** | 103 | 136 | **178** |
| -13.5 | -11.8 | -10.0 | -7.9 | -5.6 | -2.9 | 26.9 | 3.3 | 7.0 | 11.1 | 15.8 | 21.0 | 26.9 | 40.9 | 58.5 | 80.7 | 109 | 144 | 188 |
| -14.3 | -12.5 | -10.5 | -8.4 | -5.9 | -3.1 | 28.5 | 3.5 | 7.4 | 11.8 | 16.7 | 22.3 | 28.5 | 43.3 | 62.0 | 85.5 | 115 | 153 | 200 |
| -15.1 | -13.3 | -11.2 | -8.8 | -6.2 | -3.3 | 30.2 | 3.7 | 7.9 | 12.5 | 17.7 | 23.6 | 30.2 | 45.9 | 65.7 | 90.6 | 122 | 162 | 211 |
| **-16.0** | -14.0 | **-11.8** | -9.4 | **-6.6** | -3.5 | **32** | 3.9 | **8.3** | 13.3 | **18.8** | 25.0 | **32.0** | 48.6 | 69.6 | **96.0** | 129 | 171 | **224** |
| -17.0 | -14.9 | -12.5 | -9.9 | -7.0 | -3.7 | 33.9 | 4.2 | 8.8 | 14.0 | 19.9 | 26.5 | 33.9 | 51.5 | 73.7 | 102 | 137 | 181 | 237 |
| -18.0 | -15.8 | -13.3 | -10.5 | -7.4 | -3.9 | 35.9 | 4.4 | 9.3 | 14.9 | 21.1 | 28.1 | 35.9 | 54.6 | 78.1 | 108 | 145 | 192 | 251 |
| -19.0 | -16.7 | -14.1 | -11.1 | -7.9 | -4.2 | 38.1 | 4.7 | 9.9 | 15.8 | 22.4 | 29.8 | 38.1 | 57.8 | 82.8 | 114 | 154 | 204 | 266 |
| **-20.2** | -17.7 | **-14.9** | -11.8 | **-8.3** | -4.4 | **40.3** | 4.9 | **10.5** | 16.7 | **23.7** | 31.5 | **40.3** | 61.3 | 87.7 | **121** | 163 | 216 | **282** |
| -21.4 | -18.7 | -15.8 | -12.5 | -8.8 | -4.7 | 42.7 | 5.2 | 11.1 | 17.7 | 25.1 | 33.4 | 42.7 | 64.9 | 92.9 | 128 | 173 | 229 | 299 |
| -22.6 | -19.9 | -16.7 | -13.3 | -9.3 | -4.9 | 45.3 | 5.5 | 11.8 | 18.7 | 26.6 | 35.4 | 45.3 | 68.8 | 98.4 | 136 | 183 | 242 | 317 |
| -24.0 | -21.0 | -17.7 | -14.0 | -9.9 | -5.2 | 47.9 | 5.9 | 12.5 | 19.9 | 28.2 | 37.5 | 47.9 | 72.9 | 104 | 144 | 194 | 256 | 336 |
| **-25.4** | -22.3 | **-18.8** | -14.9 | **-10.5** | -5.5 | **50.8** | 6.2 | **13.2** | 21.0 | **29.8** | 39.7 | **50.8** | 77.2 | 110 | **152** | 205 | 272 | **356** |
| -26.9 | -23.6 | -19.9 | -15.8 | -11.1 | -5.9 | 53.8 | 6.6 | 14.0 | 22.3 | 31.6 | 42.1 | 53.8 | 81.8 | 117 | 161 | 217 | 288 | 377 |
| -28.5 | -25.0 | -21.1 | -16.7 | -11.8 | -6.2 | 57.0 | 7.0 | 14.8 | 23.6 | 33.5 | 44.6 | 57.0 | 86.7 | 124 | 171 | 230 | 305 | 399 |
| -30.2 | -26.5 | -22.4 | -17.7 | -12.5 | -6.6 | 60.4 | 7.4 | 15.7 | 25.0 | 35.5 | 47.2 | 60.4 | 91.8 | 131 | 181 | 244 | 323 | 423 |
| **-32.0** | -28.1 | **-23.7** | -18.7 | **-13.2** | -7.0 | **64** | 7.8 | **16.6** | 26.5 | **37.6** | 50.0 | **64.0** | 97.3 | 139 | **192** | 259 | 342 | **448** |

fig.2

# Circle of Confusion / Typical Enlargements / Required Resolution



critical viewing conditions

Minimum Visual Angles

© 2009-Jul-30 by Ralph W. Lambrecht

| | arc sec | degrees | rad | |
|---|---|---|---|---|
| detectable point | 0.05 | 13.889E-06 | 242.407E-09 | stars against black sky |
| detectable line | 1 | 277.778E-06 | 4.848E-06 | thin wire against a bright sky |
| perceptible | 10 | 2.778E-03 | 48.481E-06 | limit of actuance |
| distinguishable | 20 | 5.556E-03 | 96.963E-06 | critical minimum visual angle |
| separable | 60 | 16.667E-03 | 290.888E-06 | standard minimum visual angle |
| | 120 | 33.333E-03 | 581.776E-06 | relaxed minimum visual angle |

*The Measure of Man*
© 1967 by Henry Dreyfuss
and
*On the Psychophysical Function*
© 1975 by H. L. Resnikoff

| chosen | 20 | 5.556E-3 | 9.696E-5 | |
|---|---|---|---|---|
| **Print Details** | | Min Viewing | Eye | Enlarged Circle of |
| | Diagonal | Distance | Resolution | Confusion |
| Size | [mm] | [mm] | [lp/mm] | [mm] |
| 5x7 | 218 | 250 | 20.6 | 0.048 |
| 8x10 | 325 | 325 | 15.9 | 0.063 |
| 9.5x12 | 389 | 389 | 13.3 | 0.075 |
| 11x14 | 452 | 452 | 11.4 | 0.088 |
| 12x16 | 508 | 508 | 10.2 | 0.099 |
| 16x20 | 651 | 651 | 7.9 | 0.126 |

Negative Details

| | Diagonal full | Diagonal 4x5 | Enlargement | | | | | | Circle of Confusion | Resolution required |
|---|---|---|---|---|---|---|---|---|---|---|
| Size | [mm] | [mm] | 5x7 | 8x10 | 9.5x12 | 11x14 | 12x16 | 16x20 | [mm] | [lp/mm] |
| 16x24 | 28.8 | 25.6 | 8.5 | 12.7 | 15.2 | 17.7 | 19.8 | 25.4 | 0.005 | 201 |
| 24x36 | 43.3 | 38.4 | 5.7 | 8.5 | 10.1 | 11.8 | 13.2 | 16.9 | 0.007 | 134 |
| 6x4.5 | 69.7 | 66.4 | 3.3 | 4.9 | 5.9 | 6.8 | 7.6 | 9.8 | 0.013 | 78 |
| 6x6 | 79.2 | 71.7 | 3.0 | 4.5 | 5.4 | 6.3 | 7.1 | 9.1 | 0.014 | 72 |
| 6x7 | 88.9 | 83.2 | 2.6 | 3.9 | 4.7 | 5.4 | 6.1 | 7.8 | 0.016 | 62 |
| 6x9 | 99.8 | 89.6 | 2.4 | 3.6 | 4.3 | 5.0 | 5.7 | 7.3 | 0.017 | 58 |
| 4x5 | 153.7 | 153.7 | 1.4 | 2.1 | 2.5 | 2.9 | 3.3 | 4.2 | 0.030 | 34 |
| 5x7 | 206.5 | 192.1 | 1.1 | 1.7 | 2.0 | 2.4 | 2.6 | 3.4 | 0.037 | 27 |
| 8x10 | 307.3 | 307.3 | 0.7 | 1.1 | 1.3 | 1.5 | 1.7 | 2.1 | 0.060 | 17 |
| 11x14 | 434.2 | 432.6 | 0.5 | 0.8 | 0.9 | 1.0 | 1.2 | 1.5 | 0.084 | 12 |

standard viewing conditions

Minimum Visual Angles

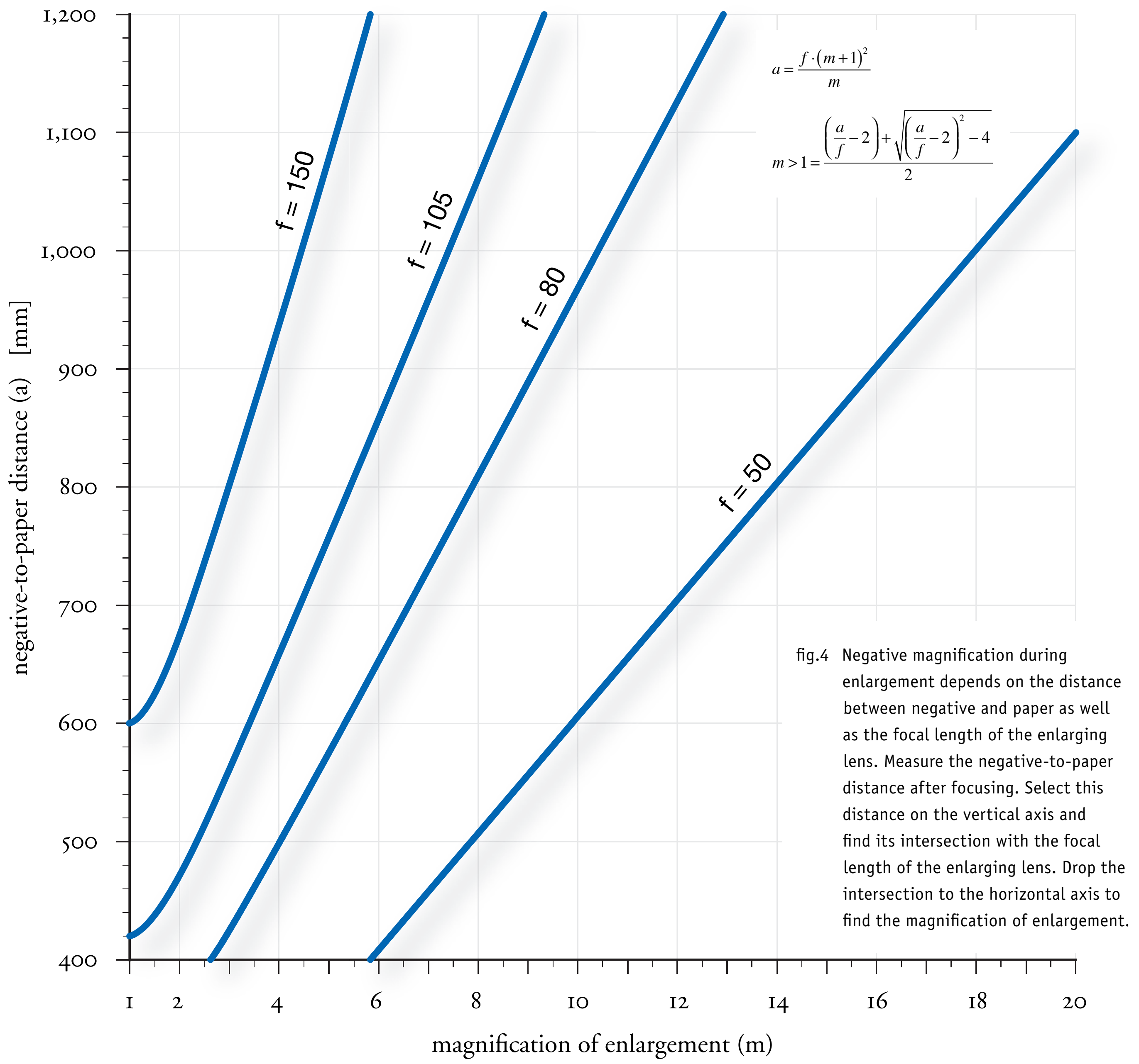
| | arc sec | degrees | rad | |
|---|---|---|---|---|
| detectable point | 0.05 | 13.889E-06 | 242.407E-09 | stars against black sky |
| detectable line | 1 | 277.778E-06 | 4.848E-06 | thin wire against a bright sky |
| perceptible | 10 | 2.778E-03 | 48.481E-06 | limit of actuance |
| distinguishable | 20 | 5.556E-03 | 96.963E-06 | critical minimum visual angle |
| separable | 60 | 16.667E-03 | 290.888E-06 | standard minimum visual angle |
| | 120 | 33.333E-03 | 581.776E-06 | relaxed minimum visual angle |

| chosen | 60 | 1.667E-2 | 2.909E-4 | |
|---|---|---|---|---|
| **Print Details** | | Min Viewing | Eye | Enlarged Circle of |
| | Diagonal | Distance | Resolution | Confusion |
| Size | [mm] | [mm] | [lp/mm] | [mm] |
| 5x7 | 218 | 250 | 6.9 | 0.145 |
| 8x10 | 325 | 325 | 5.3 | 0.189 |
| 9.5x12 | 389 | 389 | 4.4 | 0.226 |
| 11x14 | 452 | 452 | 3.8 | 0.263 |
| 12x16 | 508 | 508 | 3.4 | 0.296 |
| 16x20 | 651 | 651 | 2.6 | 0.378 |

Negative Details

| | Diagonal full | Diagonal 4x5 | Enlargement | | | | | | Circle of Confusion | Resolution required |
|---|---|---|---|---|---|---|---|---|---|---|
| Size | [mm] | [mm] | 5x7 | 8x10 | 9.5x12 | 11x14 | 12x16 | 16x20 | [mm] | [lp/mm] |
| 16x24 | 28.8 | 25.6 | 8.5 | 12.7 | 15.2 | 17.7 | 19.8 | 25.4 | 0.015 | 67 |
| 24x36 | 43.3 | 38.4 | 5.7 | 8.5 | 10.1 | 11.8 | 13.2 | 16.9 | 0.022 | 45 |
| 6x4.5 | 69.7 | 66.4 | 3.3 | 4.9 | 5.9 | 6.8 | 7.6 | 9.8 | 0.039 | 26 |
| 6x6 | 79.2 | 71.7 | 3.0 | 4.5 | 5.4 | 6.3 | 7.1 | 9.1 | 0.042 | 24 |
| 6x7 | 88.9 | 83.2 | 2.6 | 3.9 | 4.7 | 5.4 | 6.1 | 7.8 | 0.048 | 21 |
| 6x9 | 99.8 | 89.6 | 2.4 | 3.6 | 4.3 | 5.0 | 5.7 | 7.3 | 0.052 | 19 |
| 4x5 | 153.7 | 153.7 | 1.4 | 2.1 | 2.5 | 2.9 | 3.3 | 4.2 | 0.089 | 11 |
| 5x7 | 206.5 | 192.1 | 1.1 | 1.7 | 2.0 | 2.4 | 2.6 | 3.4 | 0.112 | 9 |
| 8x10 | 307.3 | 307.3 | 0.7 | 1.1 | 1.3 | 1.5 | 1.7 | 2.1 | 0.179 | 6 |
| 11x14 | 434.2 | 432.6 | 0.5 | 0.8 | 0.9 | 1.0 | 1.2 | 1.5 | 0.252 | 4 |

fig.3 Throughout the book, we make several references to standard and critical viewing conditions, the minimum circle of confusion, typical print enlargements and the lens, film or sensor resolutions required. The data compiled in these two tables are the foundation of our references.

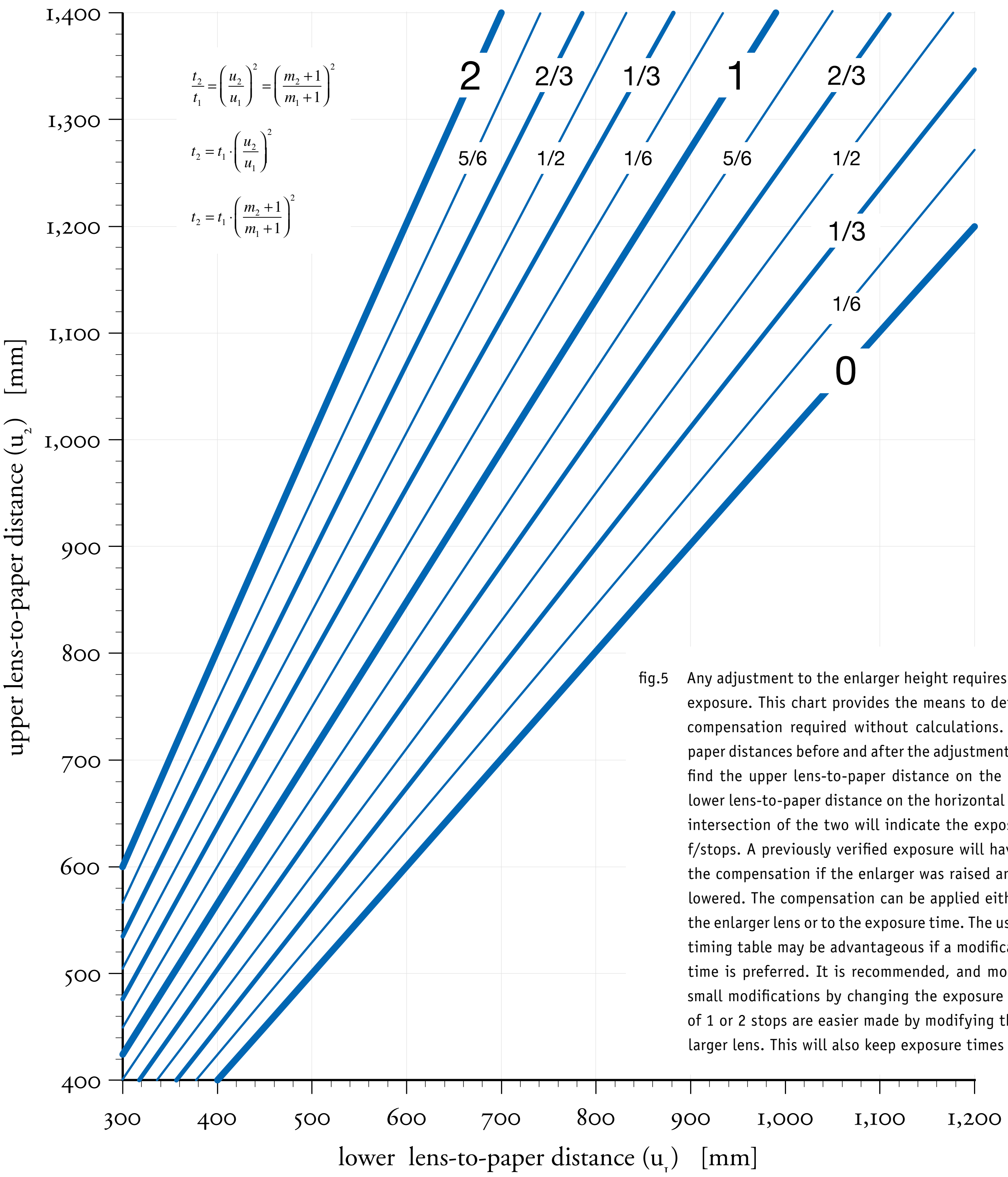


$$a = \frac{f \cdot (m+1)^2}{m}$$

$$m > 1 = \frac{\left(\frac{a}{f} - 2\right) + \sqrt{\left(\frac{a}{f} - 2\right)^2 - 4}}{2}$$

fig.4 Negative magnification during enlargement depends on the distance between negative and paper as well as the focal length of the enlarging lens. Measure the negative-to-paper distance after focusing. Select this distance on the vertical axis and find its intersection with the focal length of the enlarging lens. Drop the intersection to the horizontal axis to find the magnification of enlargement.

# Enlarger-Height Exposure Compensation



$$\frac{t_2}{t_1}=\left(\frac{u_2}{u_1}\right)^2=\left(\frac{m_2+1}{m_1+1}\right)^2$$

$$t_2=t_1\cdot\left(\frac{u_2}{u_1}\right)^2$$

$$t_2=t_1\cdot\left(\frac{m_2+1}{m_1+1}\right)^2$$

fig.5 Any adjustment to the enlarger height requires a change in the print exposure. This chart provides the means to determine the exposure compensation required without calculations. Measure the lens-to-paper distances before and after the adjustment to the enlarger. Then, find the upper lens-to-paper distance on the vertical axis and the lower lens-to-paper distance on the horizontal axis of the chart. The intersection of the two will indicate the exposure compensation in f/stops. A previously verified exposure will have to be increased by the compensation if the enlarger was raised and decreased if it was lowered. The compensation can be applied either to the aperture of the enlarger lens or to the exposure time. The use of a separate f/stop timing table may be advantageous if a modification of the exposure time is preferred. It is recommended, and more practical, to make small modifications by changing the exposure time. Larger changes, of 1 or 2 stops are easier made by modifying the aperture of the enlarger lens. This will also keep exposure times at manageable levels.

# Temperature Conversion

| °C | °F | °F | °C |
|---|---|---|---|
| **10** | 50.0 | **50** | 10.0 |
| **11** | 51.8 | **52** | 11.1 |
| **12** | 53.6 | **54** | 12.2 |
| **13** | 55.4 | **56** | 13.3 |
| **14** | 57.2 | **58** | 14.4 |
| **15** | 59.0 | **60** | 15.6 |
| **16** | 60.8 | **62** | 16.7 |
| **17** | 62.6 | **64** | 17.8 |
| **18** | 64.4 | **66** | 18.9 |
| **19** | 66.2 | **68** | 20.0 |
| **20** | 68.0 | **70** | 21.1 |
| **21** | 69.8 | **71** | 21.7 |
| **22** | 71.6 | **72** | 22.2 |
| **23** | 73.4 | **73** | 22.8 |
| **24** | 75.2 | **74** | 23.3 |
| **25** | 77.0 | **75** | 23.9 |
| **26** | 78.8 | **76** | 24.4 |
| **27** | 80.6 | **78** | 25.6 |
| **28** | 82.4 | **80** | 26.7 |
| **29** | 84.2 | **82** | 27.8 |
| **30** | 86.0 | **84** | 28.9 |
| **31** | 87.8 | **86** | 30.0 |
| **32** | 89.6 | **88** | 31.1 |
| **33** | 91.4 | **90** | 32.2 |
| **34** | 93.2 | **92** | 33.3 |
| **35** | 95.0 | **94** | 34.4 |
| **36** | 96.8 | **96** | 35.6 |
| **37** | 98.6 | **98** | 36.7 |
| **38** | 100.4 | **100** | 37.8 |
| **39** | 102.2 | **102** | 38.9 |
| **40** | 104.0 | **104** | 40.0 |

$$°F = °C \cdot \frac{9}{5} + 32$$

$$°C = \left(°F - 32\right) \cdot \frac{5}{9}$$

fig.6 Celsius is a temperature scale named after the Swedish astronomer Anders Celsius (1701–1744), who developed it two years before his death. The Fahrenheit scale is named after the physicist Daniel Gabriel Fahrenheit (1686–1736) who proposed his scale in 1724. On the Celsius scale, 0 and 100°C are defined as the freezing and boiling points of water, both measured at standard atmospheric pressure. The Celsius scale has replaced Fahrenheit in most countries, with the exception of the USA and a few other nations, where most people are still accustomed to measuring temperatures in Fahrenheit.

# Film Development Temperature Compensation

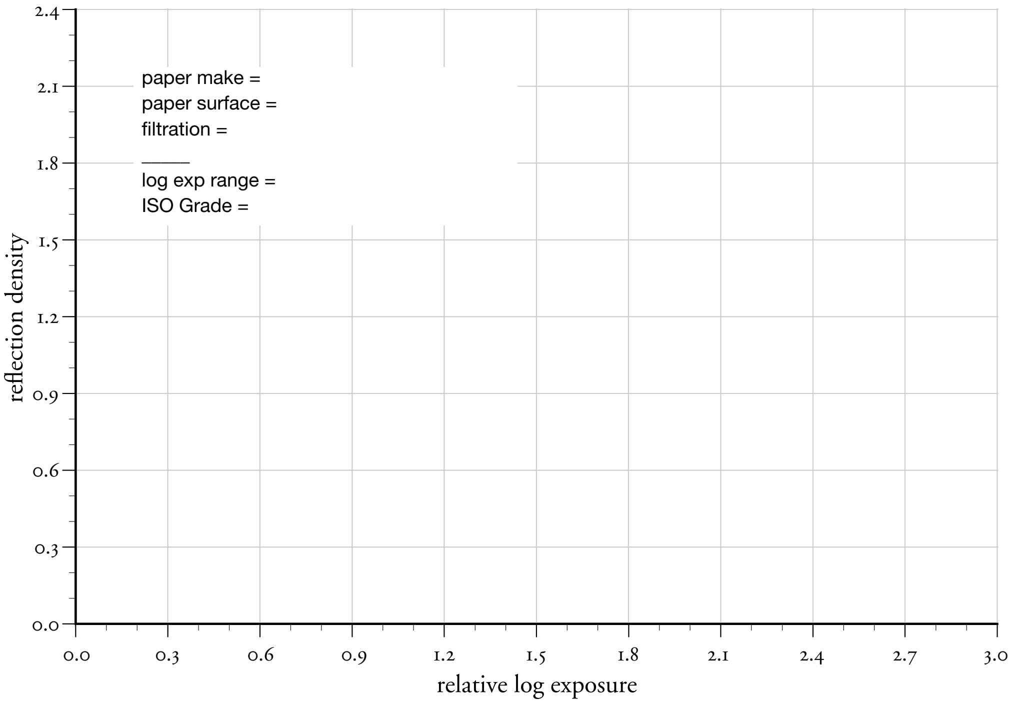
| development temperature substitutes | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 18°C 64°F | 19°C 66°F | 20°C 68°F | 21°C 70°F | 22°C 72°F | 23°C 73°F | 24°C 75°F | 25°C 77°F | 26°C 79°F | 27°C 81°F | 28°C 82°F |
| 4:50 | 4:20 | 4:00 | - | - | - | - | - | - | - | - |
| 5:20 | 5:00 | 4:30 | 4:10 | - | - | - | - | - | - | - |
| 6:00 | 5:30 | 5:00 | 4:30 | 4:10 | - | - | - | - | - | - |
| 6:40 | 6:00 | 5:30 | 5:00 | 4:40 | 4:10 | - | - | - | - | - |
| 7:10 | 6:40 | 6:00 | 5:30 | 5:00 | 4:30 | 4:10 | - | - | - | - |
| 7:50 | 7:10 | 6:30 | 6:00 | 5:30 | 5:00 | 4:30 | 4:10 | - | - | - |
| 8:20 | 7:40 | 7:00 | 6:20 | 5:50 | 5:20 | 4:50 | 4:30 | 4:00 | - | - |
| 9:00 | 8:10 | 7:30 | 6:50 | 6:20 | 5:40 | 5:10 | 4:50 | 4:20 | - | - |
| 9:40 | 8:50 | 8:00 | 7:20 | 6:40 | 6:10 | 5:30 | 5:00 | 4:40 | 4:10 | - |
| 10:10 | 9:20 | 8:30 | 7:50 | 7:10 | 6:30 | 5:50 | 5:20 | 4:50 | 4:30 | 4:10 |
| 10:50 | 9:50 | 9:00 | 8:10 | 7:30 | 6:50 | 6:10 | 5:40 | 5:10 | 4:40 | 4:20 |
| 11:30 | 10:30 | 9:30 | 8:40 | 8:00 | 7:10 | 6:40 | 6:00 | 5:30 | 5:00 | 4:30 |
| 12:00 | 11:00 | 10:00 | 9:10 | 8:20 | 7:40 | 7:00 | 6:20 | 5:50 | 5:20 | 4:50 |
| 13:10 | 12:00 | 11:00 | 10:00 | 9:10 | 8:20 | 7:40 | 7:00 | 6:20 | 5:50 | 5:20 |
| 14:30 | 13:10 | 12:00 | 11:00 | 10:00 | 9:10 | 8:20 | 7:40 | 7:00 | 6:20 | 5:50 |
| 15:40 | 14:20 | 13:00 | 11:50 | 10:50 | 9:50 | 9:00 | 8:10 | 7:30 | 6:50 | 6:20 |
| 16:50 | 15:20 | 14:00 | 12:50 | 11:40 | 10:40 | 9:40 | 8:50 | 8:10 | 7:20 | 6:40 |
| 18:00 | 16:30 | 15:00 | 13:40 | 12:30 | 11:20 | 10:20 | 9:30 | 8:40 | 7:50 | 7:10 |
| 19:10 | 17:30 | 16:00 | 14:40 | 13:20 | 12:10 | 11:10 | 10:10 | 9:10 | 8:30 | 7:40 |
| 20:30 | 18:40 | 17:00 | 15:30 | 14:10 | 13:00 | 11:50 | 10:50 | 9:50 | 9:00 | 8:10 |
| 21:40 | 19:40 | 18:00 | 16:30 | 15:00 | 13:40 | 12:30 | 11:20 | 10:20 | 9:30 | 8:40 |
| 22:50 | 20:50 | 19:00 | 17:20 | 15:50 | 14:30 | 13:10 | 12:00 | 11:00 | 10:00 | 9:10 |
| 24:00 | 22:00 | 20:00 | 18:20 | 16:40 | 15:10 | 13:50 | 12:40 | 11:30 | 10:30 | 9:40 |
| 25:10 | 23:00 | 21:00 | 19:10 | 17:30 | 16:00 | 14:30 | 13:20 | 12:10 | 11:00 | 10:10 |
| 26:30 | 24:10 | 22:00 | 20:00 | 18:20 | 16:40 | 15:20 | 14:00 | 12:40 | 11:40 | 10:30 |

$$\log c = \frac{(\log t_2 - \log t_1) \cdot 10}{T_1 - T_2}$$

$$t_2 = t_1 \cdot c^{\frac{T_1 - T_2}{10}}$$

fig.7 To achieve consistent film development at different temperatures, a temperature coefficient (c) is used to calculate a new development time ($t_2$) for a new temperature ($T_2$) from an old development time ($t_1$) and an old temperature ($T_1$). For the table shown here, a coefficient of 2.5 was used to account for the temperature effect on D-23, D-76 and ID-11.
In the column with your standard development temperature, find the row with your target development time. Follow that row, left or right, until you reach the column with the actual processing temperature and find the new development time. For example, if 10 minutes at 20°C is your standard film development process, you need to reduce the development time to 6 minutes and 20 seconds if the processing temperature changes to 25°C.

# Paper Characteristic Curves



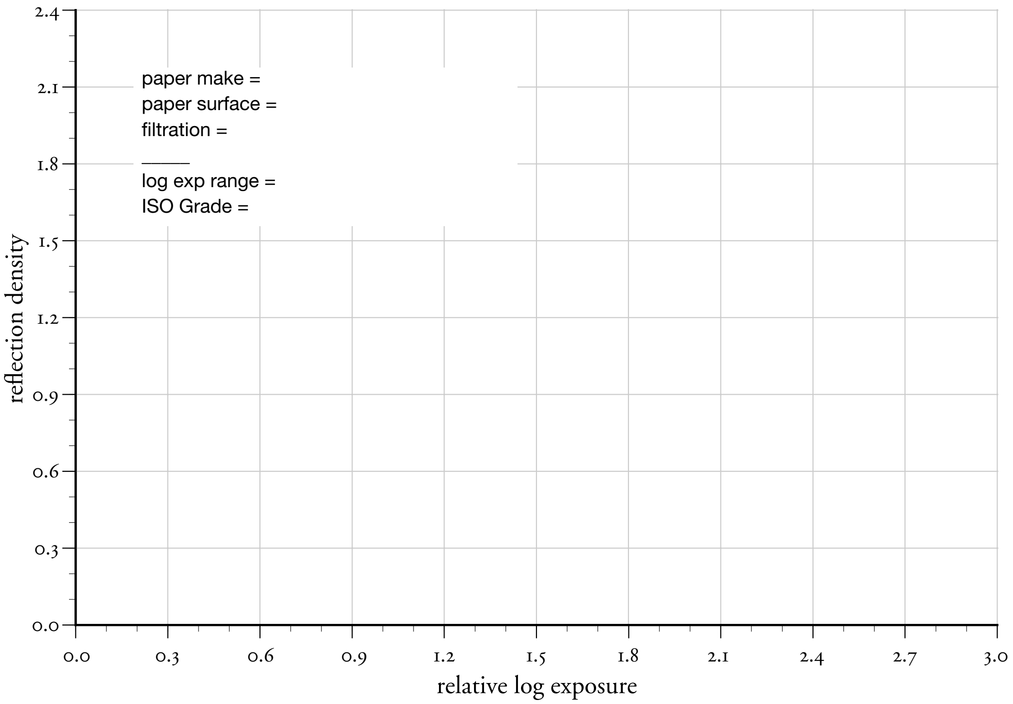


fig.8 This template is used to chart paper characteristic curves. First, record the paper specifications and contrast-filtration method. Then, conduct the test as described in ‘Measuring Paper Contrast’ and chart the data on one of these sheets. Use the template in fig.12 as an overlay to measure the log exposure range and the table in fig.9 to determine the corresponding ISO grade.
(do not change the scale of this template)

# Paper Log Exposure Range / Standard ISO Paper Grade

$$ISO = 9.21 - 7.80\cdot(LER) + 0.421\cdot(LER)^2 + 0.486\cdot(LER)^3$$

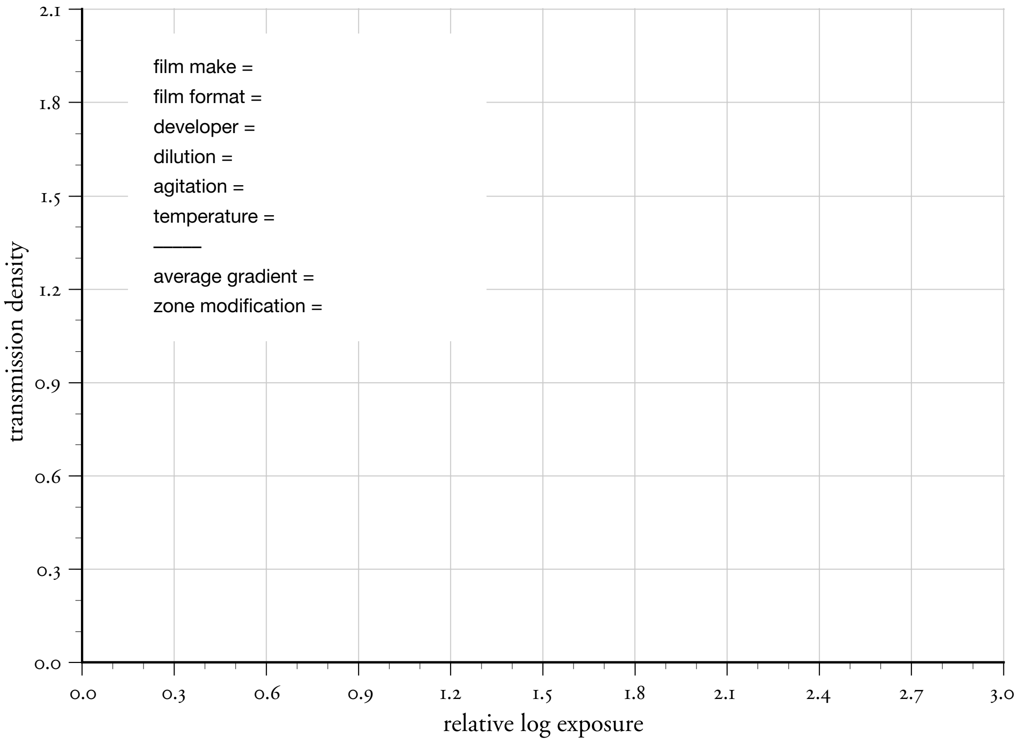
$$LER = 1.55 - 0.306\cdot(ISO) + 0.0349\cdot(ISO)^2 - 0.00250\cdot(ISO)^3$$

| log ER | ISO | log ER | ISO | log ER | ISO |
|---|---|---|---|---|---|
| 0.50 | 5.52 | 0.90 | 2.85 | 1.30 | 0.87 |
| 0.51 | 5.45 | 0.91 | 2.79 | 1.31 | 0.83 |
| 0.52 | 5.38 | 0.92 | 2.73 | 1.32 | 0.80 |
| 0.53 | 5.32 | 0.93 | 2.67 | 1.33 | 0.76 |
| 0.54 | 5.25 | 0.94 | 2.61 | 1.34 | 0.72 |
| 0.55 | 5.18 | 0.95 | 2.55 | 1.35 | 0.68 |
| 0.56 | 5.11 | 0.96 | 2.49 | 1.36 | 0.65 |
| 0.57 | 5.04 | 0.97 | 2.44 | 1.37 | 0.61 |
| 0.58 | 4.97 | 0.98 | 2.38 | 1.38 | 0.58 |
| 0.59 | 4.90 | 0.99 | 2.32 | 1.39 | 0.54 |
| 0.60 | 4.83 | 1.00 | 2.27 | 1.40 | 0.51 |
| 0.61 | 4.76 | 1.01 | 2.21 | 1.41 | 0.47 |
| 0.62 | 4.69 | 1.02 | 2.16 | 1.42 | 0.44 |
| 0.63 | 4.63 | 1.03 | 2.10 | 1.43 | 0.40 |
| 0.64 | 4.56 | 1.04 | 2.05 | 1.44 | 0.37 |
| 0.65 | 4.49 | 1.05 | 2.00 | 1.45 | 0.34 |
| 0.66 | 4.42 | 1.06 | 1.95 | 1.46 | 0.30 |
| 0.67 | 4.35 | 1.07 | 1.90 | 1.47 | 0.27 |
| 0.68 | 4.28 | 1.08 | 1.85 | 1.48 | 0.24 |
| 0.69 | 4.21 | 1.09 | 1.80 | 1.49 | 0.20 |
| 0.70 | 4.14 | 1.10 | 1.75 | 1.50 | 0.17 |
| 0.71 | 4.08 | 1.11 | 1.70 | 1.51 | 0.14 |
| 0.72 | 4.01 | 1.12 | 1.65 | 1.52 | 0.10 |
| 0.73 | 3.94 | 1.13 | 1.60 | 1.53 | 0.07 |
| 0.74 | 3.87 | 1.14 | 1.55 | 1.54 | 0.04 |
| 0.75 | 3.81 | 1.15 | 1.51 | 1.55 | 0.01 |
| 0.76 | 3.74 | 1.16 | 1.46 | 1.56 | -0.03 |
| 0.77 | 3.67 | 1.17 | 1.41 | 1.57 | -0.06 |
| 0.78 | 3.61 | 1.18 | 1.37 | 1.58 | -0.09 |
| 0.79 | 3.54 | 1.19 | 1.33 | 1.59 | -0.12 |
| 0.80 | 3.48 | 1.20 | 1.28 | 1.60 | -0.16 |
| 0.81 | 3.41 | 1.21 | 1.24 | 1.61 | -0.19 |
| 0.82 | 3.35 | 1.22 | 1.20 | 1.62 | -0.22 |
| 0.83 | 3.28 | 1.23 | 1.15 | 1.63 | -0.26 |
| 0.84 | 3.22 | 1.24 | 1.11 | 1.64 | -0.29 |
| 0.85 | 3.16 | 1.25 | 1.07 | 1.65 | -0.33 |
| 0.86 | 3.09 | 1.26 | 1.03 | 1.66 | -0.36 |
| 0.87 | 3.03 | 1.27 | 0.99 | 1.67 | -0.40 |
| 0.88 | 2.97 | 1.28 | 0.95 | 1.68 | -0.43 |
| 0.89 | 2.91 | 1.29 | 0.91 | 1.69 | -0.47 |
| 0.90 | 2.85 | 1.30 | 0.87 | 1.70 | -0.50 |

| ISO | log ER |
|---|---|
| 0.000 | 1.54 |
| 0.125 | 1.51 |
| 0.250 | 1.47 |
| 0.375 | 1.43 |
| 0.500 | 1.40 |
| 0.625 | 1.37 |
| 0.750 | 1.33 |
| 0.875 | 1.30 |
| 1.000 | 1.27 |
| 1.125 | 1.24 |
| 1.250 | 1.21 |
| 1.375 | 1.18 |
| 1.500 | 1.16 |
| 1.625 | 1.13 |
| 1.750 | 1.10 |
| 1.875 | 1.08 |
| 2.000 | 1.05 |
| 2.125 | 1.03 |
| 2.250 | 1.00 |
| 2.375 | 0.98 |
| 2.500 | 0.96 |
| 2.625 | 0.94 |
| 2.750 | 0.92 |
| 2.875 | 0.89 |
| 3.000 | 0.87 |
| 3.125 | 0.85 |
| 3.250 | 0.83 |
| 3.375 | 0.81 |
| 3.500 | 0.79 |
| 3.625 | 0.78 |
| 3.750 | 0.76 |
| 3.875 | 0.74 |
| 4.000 | 0.72 |
| 4.125 | 0.70 |
| 4.250 | 0.68 |
| 4.375 | 0.67 |
| 4.500 | 0.65 |
| 4.625 | 0.63 |
| 4.750 | 0.61 |
| 4.875 | 0.59 |
| 5.000 | 0.58 |

fig.9 There is a numerical relationship between standard ISO paper grades (ISO) and the paper's log exposure range (log ER or LER).

## Film Characteristic Curves



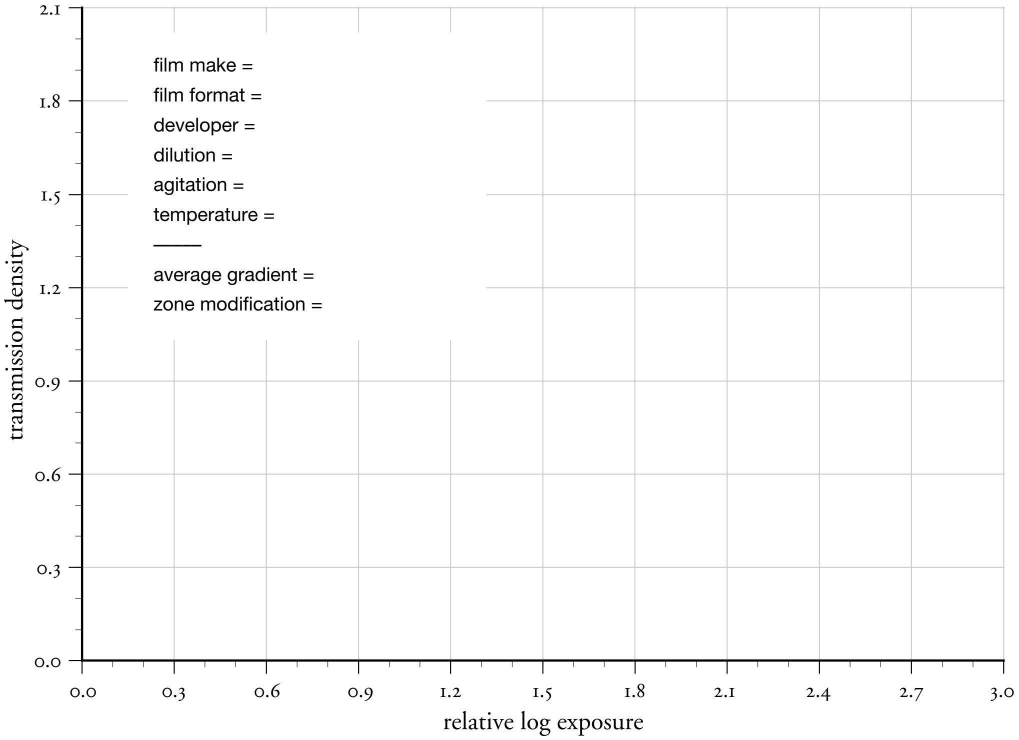


fig.10 This template is used to chart film characteristic curves. First, record the film and development specifications. Then, conduct the test as described in 'Customizing Film Speed and Development' and chart the data on one of these sheets. Use the template in fig.13 as an overlay to measure the average gradient and the table in fig.11 to determine the corresponding zone modification.
(do not change the scale of this template)

# Film Average Gradient, Zone System and Subject Brightness Range

| avg gradient | N | SBR | avg gradient | N | SBR |
|---|---|---|---|---|---|
| 0.400 | -3.0 | 10.0 | 0.571 | 0.0 | 7.0 |
| 0.404 | -2.9 | 9.9 | 0.580 | 0.1 | 6.9 |
| 0.408 | -2.8 | 9.8 | 0.588 | 0.2 | 6.8 |
| 0.412 | -2.7 | 9.7 | 0.597 | 0.3 | 6.7 |
| 0.417 | -2.6 | 9.6 | 0.606 | 0.4 | 6.6 |
| 0.421 | -2.5 | 9.5 | 0.615 | 0.5 | 6.5 |
| 0.426 | -2.4 | 9.4 | 0.625 | 0.6 | 6.4 |
| 0.430 | -2.3 | 9.3 | 0.635 | 0.7 | 6.3 |
| 0.435 | -2.2 | 9.2 | 0.645 | 0.8 | 6.2 |
| 0.440 | -2.1 | 9.1 | 0.656 | 0.9 | 6.1 |
| 0.444 | -2.0 | 9.0 | 0.667 | 1.0 | 6.0 |
| 0.449 | -1.9 | 8.9 | 0.678 | 1.1 | 5.9 |
| 0.455 | -1.8 | 8.8 | 0.690 | 1.2 | 5.8 |
| 0.460 | -1.7 | 8.7 | 0.702 | 1.3 | 5.7 |
| 0.465 | -1.6 | 8.6 | 0.714 | 1.4 | 5.6 |
| 0.471 | -1.5 | 8.5 | 0.727 | 1.5 | 5.5 |
| 0.476 | -1.4 | 8.4 | 0.741 | 1.6 | 5.4 |
| 0.482 | -1.3 | 8.3 | 0.755 | 1.7 | 5.3 |
| 0.488 | -1.2 | 8.2 | 0.769 | 1.8 | 5.2 |
| 0.494 | -1.1 | 8.1 | 0.784 | 1.9 | 5.1 |
| 0.500 | -1.0 | 8.0 | 0.800 | 2.0 | 5.0 |
| 0.506 | -0.9 | 7.9 | 0.816 | 2.1 | 4.9 |
| 0.513 | -0.8 | 7.8 | 0.833 | 2.2 | 4.8 |
| 0.519 | -0.7 | 7.7 | 0.851 | 2.3 | 4.7 |
| 0.526 | -0.6 | 7.6 | 0.870 | 2.4 | 4.6 |
| 0.533 | -0.5 | 7.5 | 0.889 | 2.5 | 4.5 |
| 0.541 | -0.4 | 7.4 | 0.909 | 2.6 | 4.4 |
| 0.548 | -0.3 | 7.3 | 0.930 | 2.7 | 4.3 |
| 0.556 | -0.2 | 7.2 | 0.952 | 2.8 | 4.2 |
| 0.563 | -0.1 | 7.1 | 0.976 | 2.9 | 4.1 |
| 0.571 | 0.0 | 7.0 | 1.000 | 3.0 | 4.0 |

$$\gamma = \frac{1.2}{2.1 - (N \cdot 0.3)}$$

$$N = \frac{2.1 - \dfrac{1.2}{\gamma}}{0.3}$$

$$SBR = 7 - N$$

fig.11 There is a numerical relationship between the average gradient, the zone modification (N) and the potential subject brightness range (SBR).

## Paper Range and Grade Meter

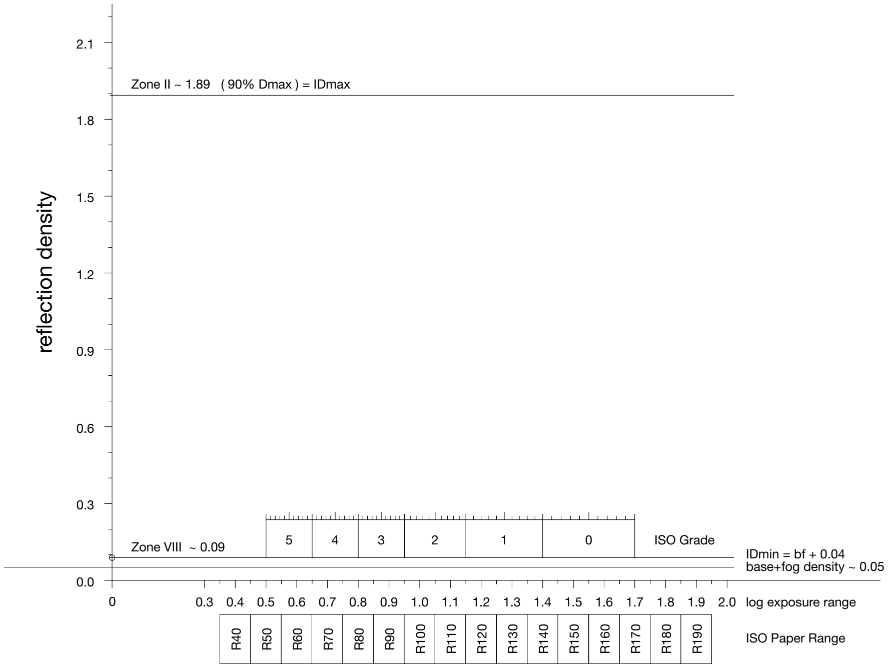


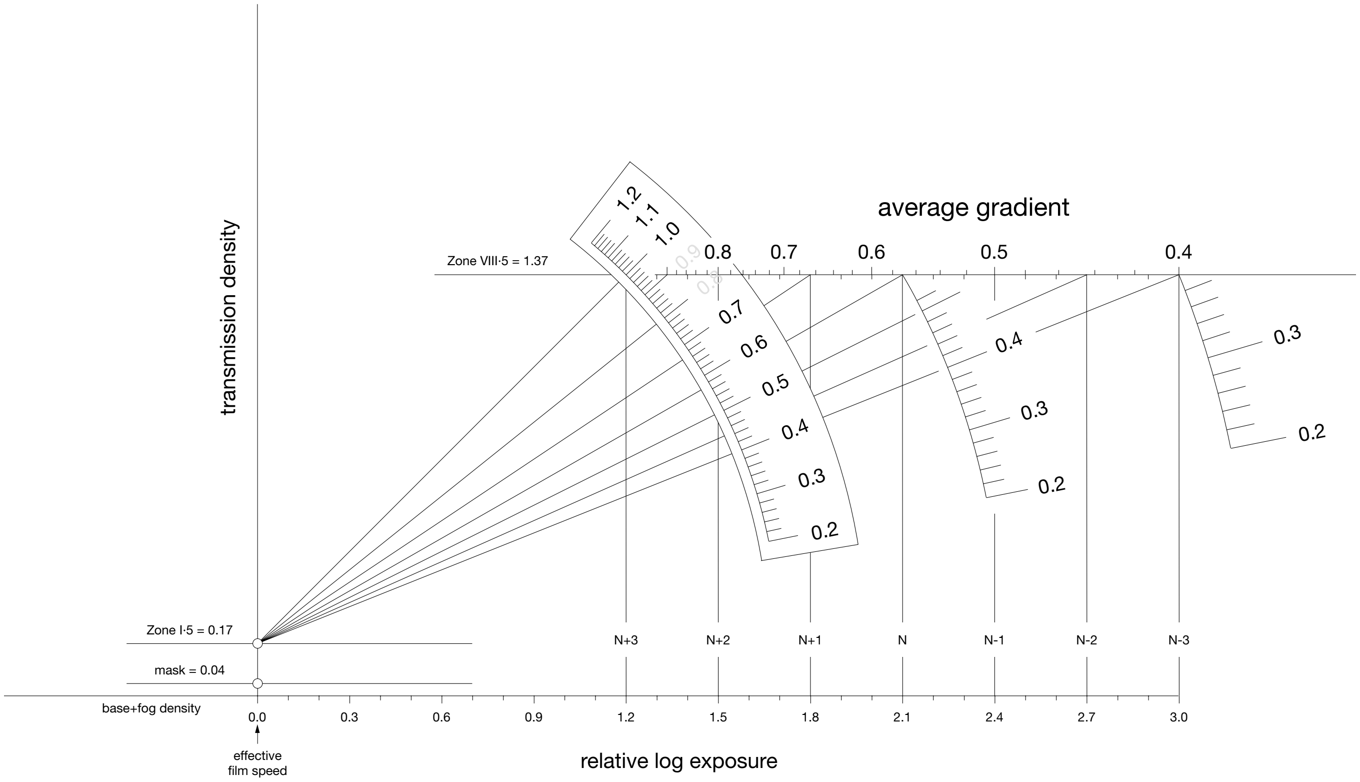
fig.12 (left) This template is used as an overlay to measure a paper's log exposure range in combination with fig.8.

(copy onto transparent material but do not change the scale of this template)

fig.13 (below) This template is used as an overlay to measure a film's average gradient in combination with fig.10.

(copy onto transparent material but do not change the scale of this template)

## Film Average Gradient Meter



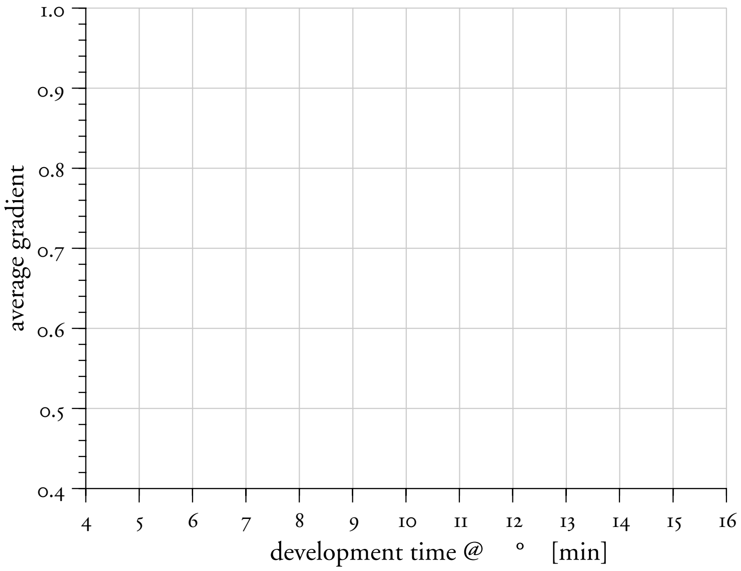
# Film Test Summary

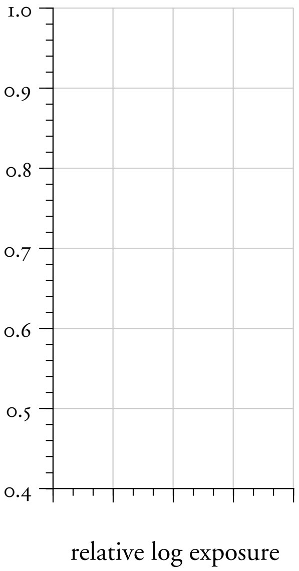
| SBR | Zone | γ |
|---|---|---|
| 10 | N-3 | 0.40 |
| 9 | N-2 | 0.44 |
| 8 | N-1 | 0.50 |
| 7 | N | 0.57 |
| 6 | N+1 | 0.67 |
| 5 | N+2 | 0.80 |
| 4 | N+3 | 1.00 |

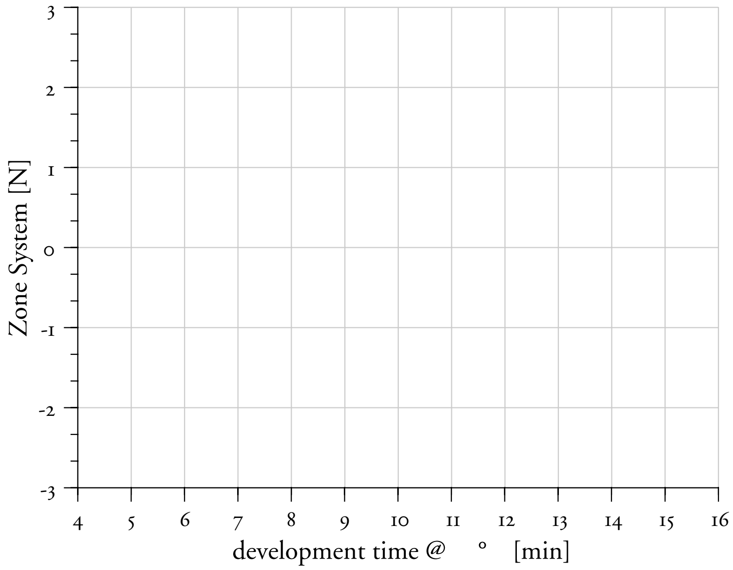
pictorial range :
Zone I·5 = 0.17 – Zone VIII·5 = 1.37
textural range :
Zone II = 0.24 – Zone VIII = 1.29
negative density range ( I·5 – VIII·5 ) = 1.2
normal subject brightness range = 2.1
speed point = 0.17

© 2008-Oct-26 Ralph W. Lambrecht

film make =
film format =
developer =
dilution =
agitation =
temperature =
date =







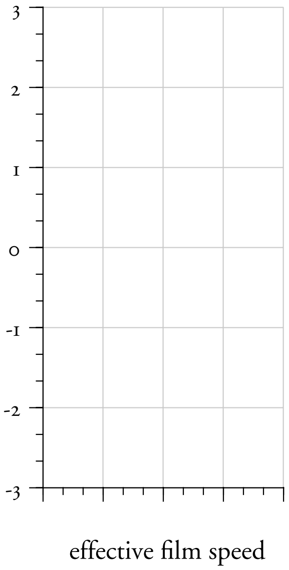
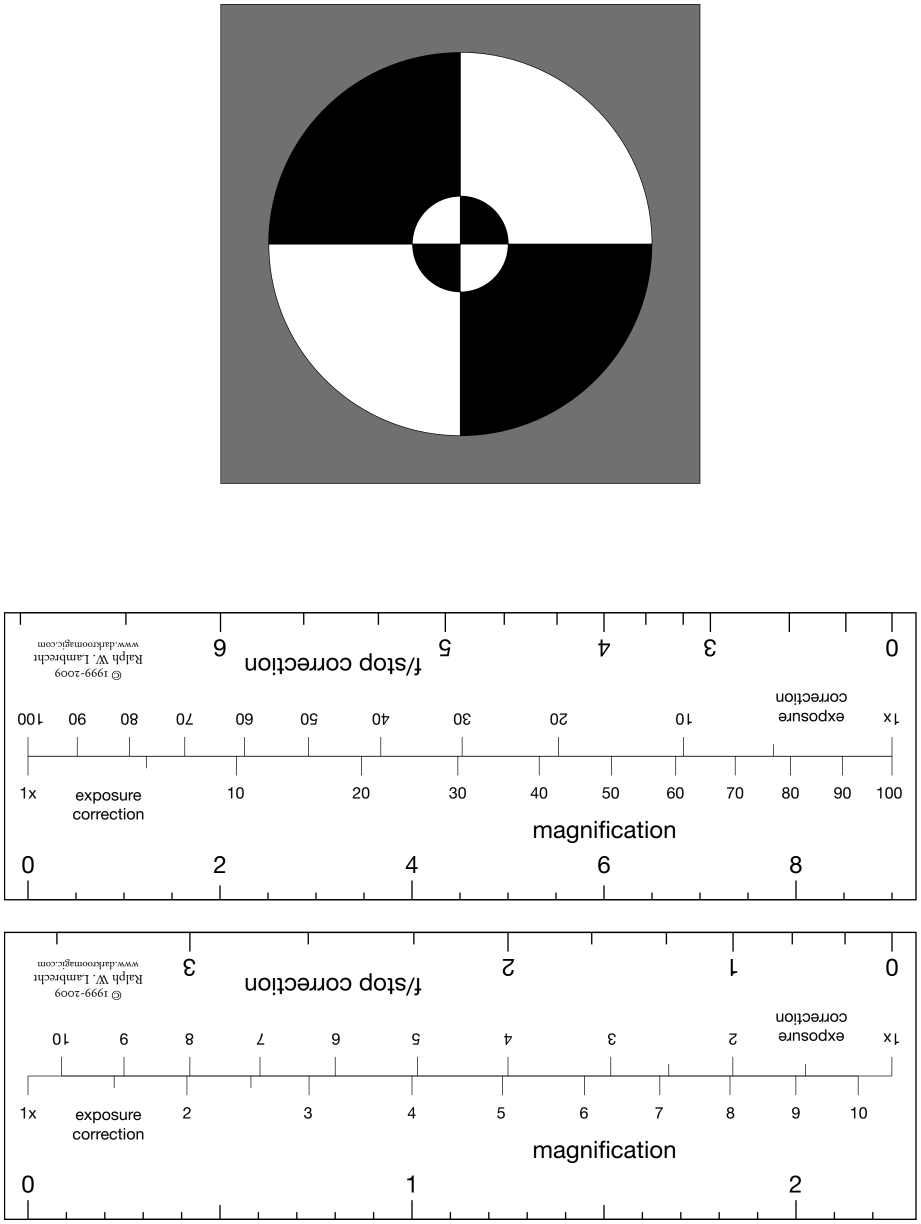


fig.14 Serious Zone System practitioners want to calibrate their favorite film/developer combinations to customized conditions. Once accomplished, most lighting conditions can be mastered with confidence and ease, rendering any negative a hassle-free printing assignment, while leaving paper grade latitude to imagination and providing maximum flexibility for creative interpretation. In ‘Customizing Film Speed and Development’, a detailed description of custom calibration was given, and figures 10, 11 and 13 provide the table and templates required to create the required information, so they can be summarized and completed here.

# Bellows Target and Rulers


0
3
4
5
6
f/stop correction
© 1999-2009
Ralph W. Lambrecht
www.darkroomagic.com
1x
exposure
correction
10
20
30
40
50
60
70
80
90
100
1x
exposure
correction
10
20
30
40
50
60
70
80
90
100
magnification
0
2
4
6
8
0
1
2
3
f/stop correction
© 1999-2009
Ralph W. Lambrecht
www.darkroomagic.com
1x
exposure
correction
2
3
4
5
6
7
8
9
10
1x
exposure
correction
2
3
4
5
6
7
8
9
10
magnification
0
1
2

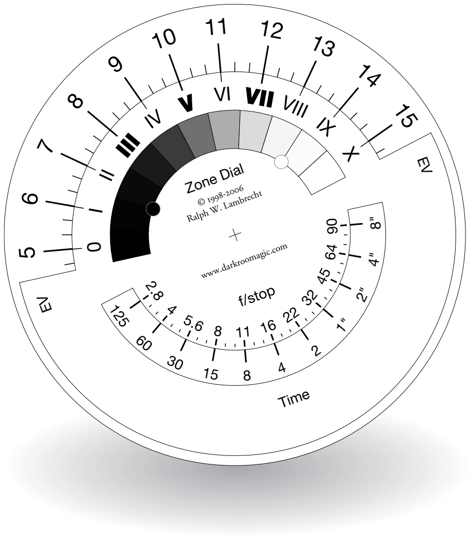
$$e=(m+1)^2$$

$$n=\frac{\log(m+1)\cdot 2}{\log 2}$$

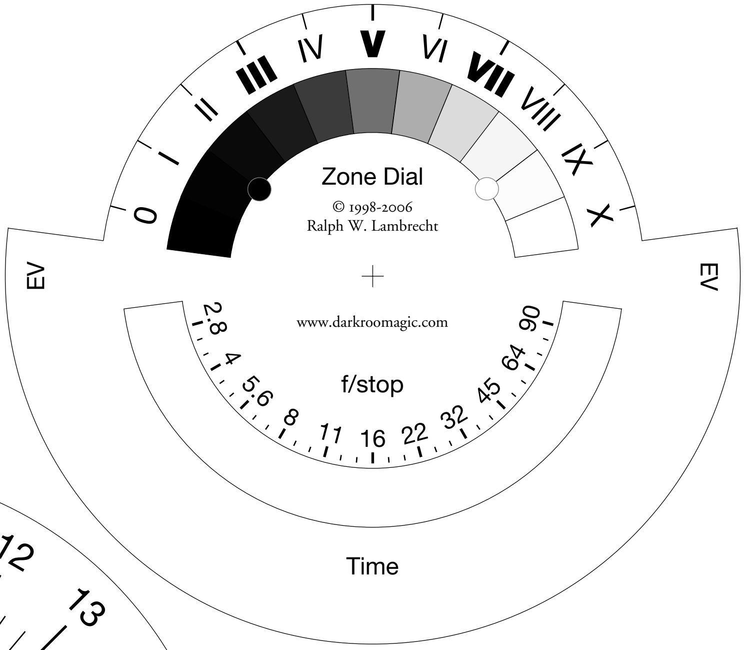
fig.15 View camera users copy the target (top) and the two rulers (below) onto separate pieces of heavy paper stock. Assemble the rulers back-to-back, and laminate each piece with clear tape to make a more durable tool. For close-up photography, place the target into the scene, and measure the diameter of the outer circle on the view screen with the bottom ruler. Determine subject magnification and f/stop correction to adjust exposure by opening lens aperture or extend shutter exposure. The inner circle, in combination with the top ruler, is provided for extreme close-up photography.

(do not change the scale of these templates)

# The Zone Dial


Zone Dial
© 1998-2006
Ralph W. Lambrecht
www.darkroomagic.com
f/stop
Time
EV
0
I
II
III
IV
V
VI
VII
VIII
IX
X

Zone Dial assembled
(reduced view)


0
I
II
III
IV
V
VI
VII
VIII
IX
X
EV
EV
Zone Dial
© 1998-2006
Ralph W. Lambrecht
www.darkroomagic.com
f/stop
2.8
4
5.6
8
11
16
22
32
45
64
90
Time

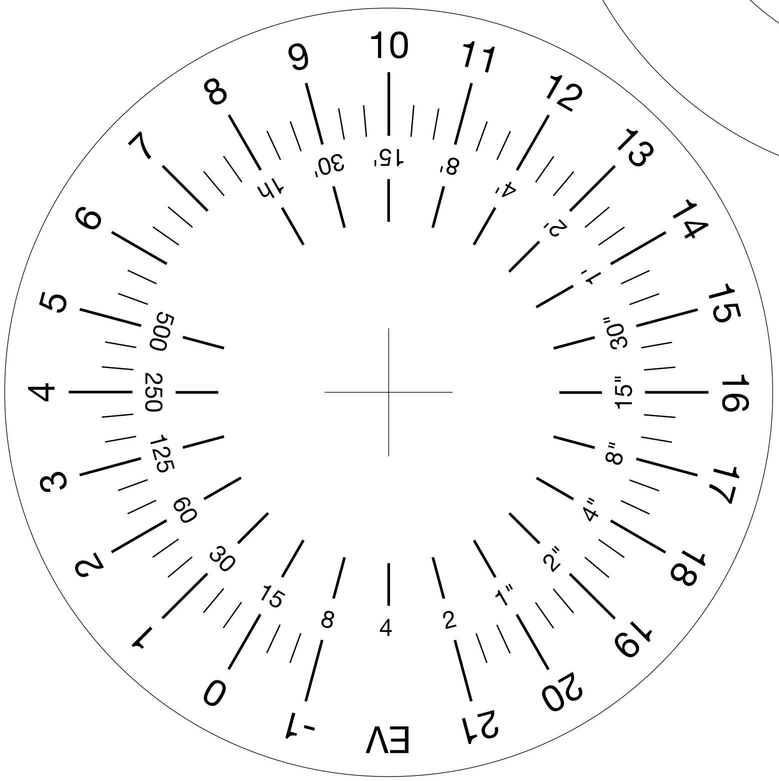
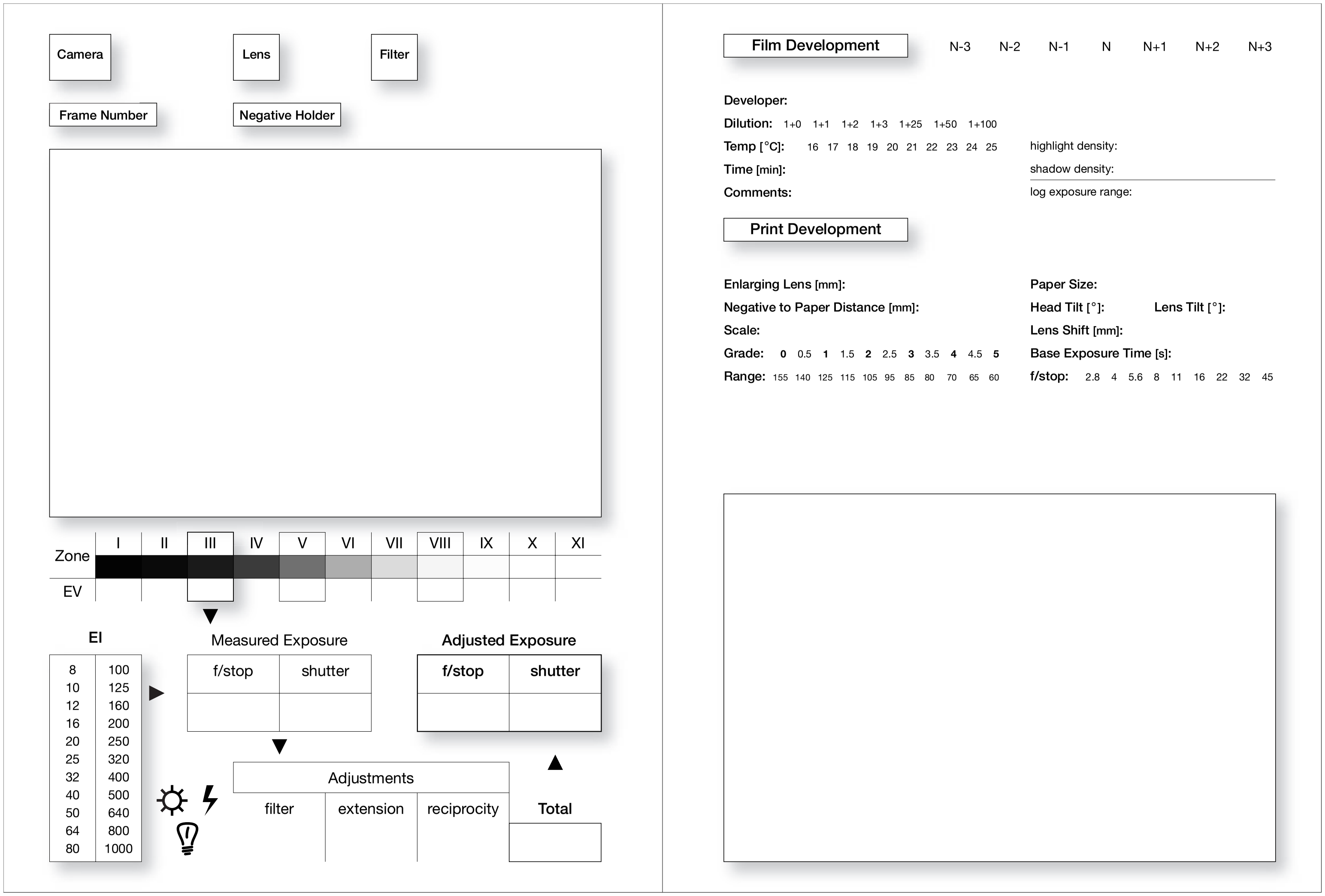

EV
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
1h
30'
15'
8'
4'
2'
1'
30"
15"
8"
4"
2"
1"
2
4
8
15
30
60
125
250
500

fig.16 The Zone Dial provides a visual reference to the way subject brightness will be represented in the final print. Zone III and VII are marked to place shadow and highlight details, and the tonality extremes of Zone I•5 and VIII•5 are identified as black and white points. All scales are in standard shutter speeds, f/stops and EVs. Meter the subject values in EVs, and correlate them to the intended Zones on the dial. This will give you an overview of the subject brightness range and several exposure recommendations. However, potential reciprocity failure has not been accounted for.

# Exposure, Development and Printing Record



Camera

Lens

Filter

Frame Number

Negative Holder

| Zone | I | II | III | IV | V | VI | VII | VIII | IX | X | XI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| EV | | | | | | | | | | | |

| EI | |
|---|---|
| 8 | 100 |
| 10 | 125 |
| 12 | 160 |
| 16 | 200 |
| 20 | 250 |
| 25 | 320 |
| 32 | 400 |
| 40 | 500 |
| 50 | 640 |
| 64 | 800 |
| 80 | 1000 |

Measured Exposure

| f/stop | shutter |
|---|---|
| | |

**Adjusted Exposure**

| **f/stop** | **shutter** |
|---|---|
| | |

Adjustments

| filter | extension | reciprocity |
|---|---|---|
| | | |

**Total**

Film Development N-3 N-2 N-1 N N+1 N+2 N+3

**Developer:**
**Dilution:** 1+0 1+1 1+2 1+3 1+25 1+50 1+100
**Temp [°C]:** 16 17 18 19 20 21 22 23 24 25
**Time** [min]:
**Comments:**

highlight density:
shadow density:
log exposure range:

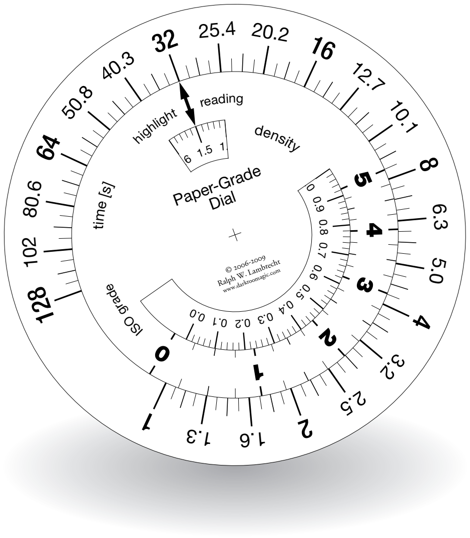
Print Development

**Enlarging Lens** [mm]:
**Negative to Paper Distance** [mm]:
**Scale:**
**Grade:** **0** 0.5 **1** 1.5 **2** 2.5 **3** 3.5 **4** 4.5 **5**
**Range:** 155 140 125 115 105 95 85 80 70 65 60

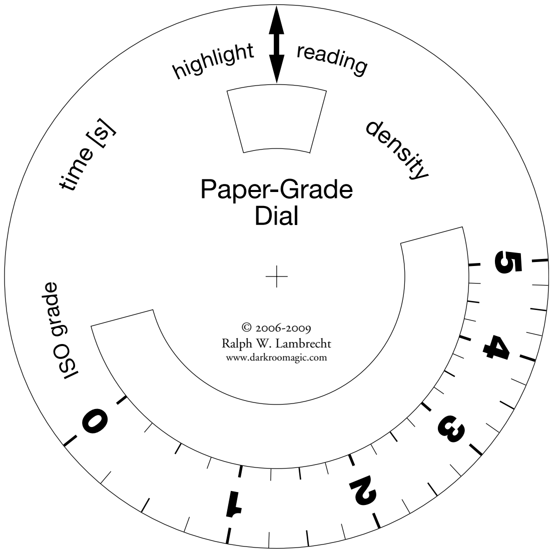
**Paper Size:**
**Head Tilt** [°]: **Lens Tilt** [°]:
**Lens Shift** [mm]:
**Base Exposure Time** [s]:
**f/stop:** 2.8 4 5.6 8 11 16 22 32 45

fig.17 Keeping accurate exposure and printing records are bureaucratic tasks many photographers avoid due to the initial workload required to obtain them. They do, however, provide significant clues to the 'things gone wrong' and allow for a certain repeatability of the overall photographic process. In 'Exposure, Development and Printing Records', we explained how to take them. This template provides the means to keep them.

# The Paper-Grade Dial


32
25.4
20.2
16
12.7
10.1
8
6.3
5.0
4
3.2
2.5
2
1.6
1.3
1
128
102
80.6
64
50.8
40.3
highlight
reading
density
6
1.5
1
time [s]
Paper-Grade Dial
ISO grade
© 2006-2009
Ralph W. Lambrecht
www.darkroomagic.com
0
1
2
3
4
5
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Paper-Grade Dial assembled
(reduced view)


highlight
reading
time [s]
density
Paper-Grade Dial
ISO grade
© 2006-2009
Ralph W. Lambrecht
www.darkroomagic.com
0
1
2
3
4
5

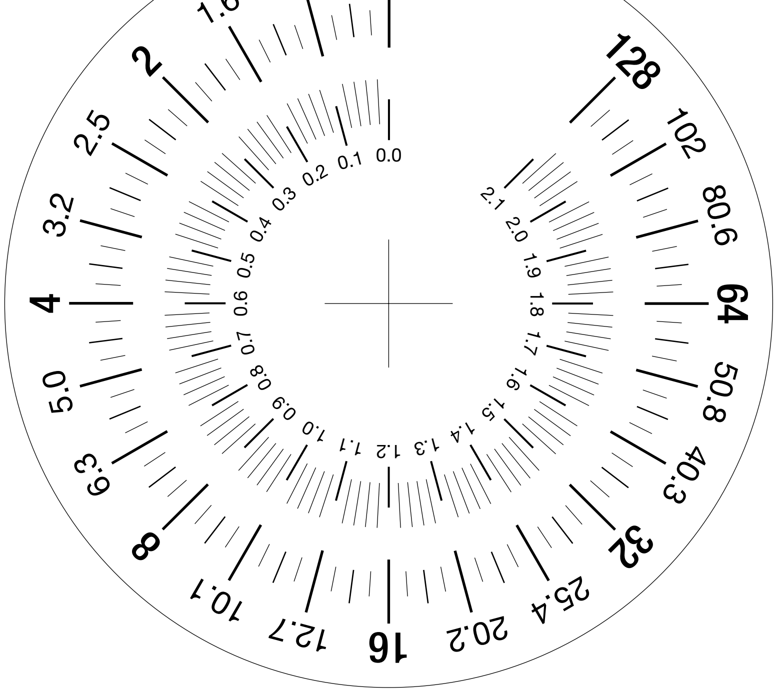
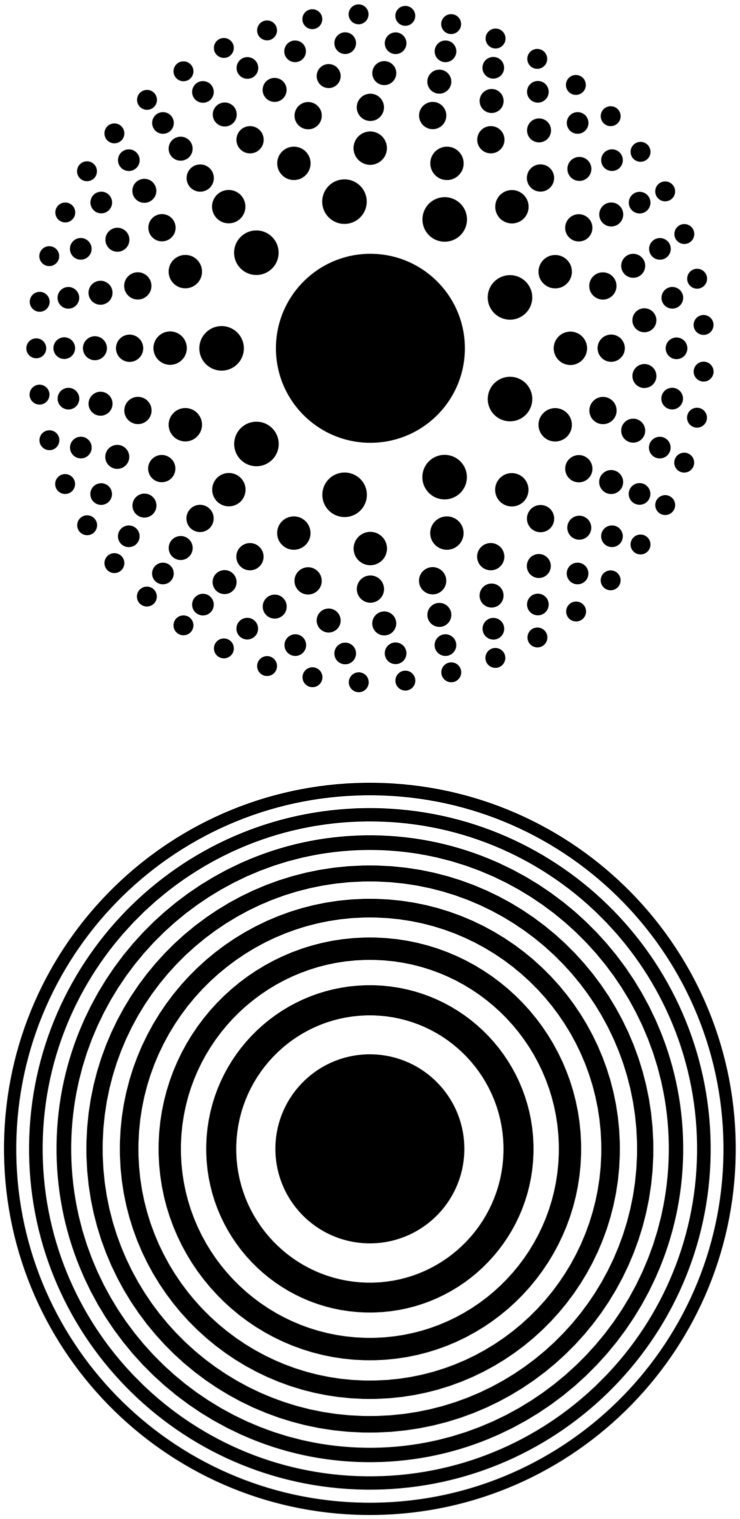

1
1.3
1.6
2
2.5
3.2
4
5.0
6.3
8
10.1
12.7
16
20.2
25.4
32
40.3
50.8
64
80.6
102
128
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1

fig.18 The Paper-Grade Dial provides a simple method to calculate the overall paper contrast required to transfer the negative density range to the print density range. Using a densitometer or a simple enlarger meter, take a textural highlight reading and set the negative density or measured exposure time on the dial. Then, take a textural shadow reading, and next to its location on the dial, read off the required ISO paper grade to capture the entire textural negative density range on paper.

## Pinhole and Zone Plate Pattern

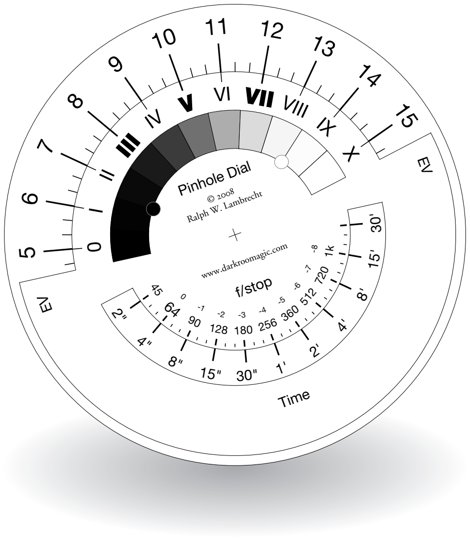


$$u = \frac{f}{m} + f$$

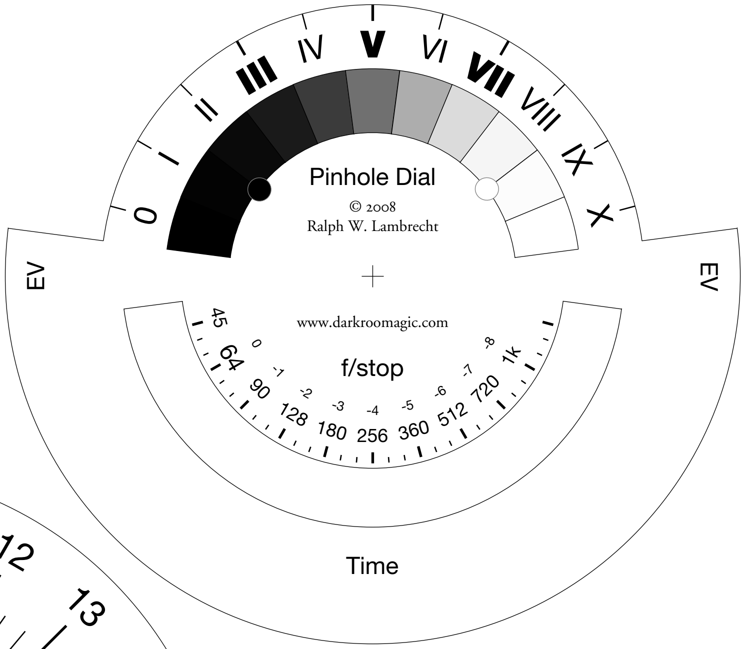
$$a = \frac{f \cdot (m+1)^2}{m}$$

fig.19 Photon sieves (top) and diffraction zone plates (bottom) are worthwhile alternatives to plain pinholes, but they cannot be cut or drilled like a simple hole. The best way of making them is to take an enlarged, tone-reversed design and photograph it onto high-contrast B&W film thus reducing it to the desired size. The two designs shown here have a center pinhole diameter of 25 mm. Using the equations above, photograph these designs with a focal length (f) from a lens-to-design distance (u), or a film-to-design distance (a), in order to reduce the patterns by a known magnification (m), and create the required size on transparent film.

# The Pinhole Dial


5
6
7
8
9
10
11
12
13
14
15
0
I
II
III
IV
V
VI
VII
VIII
IX
X
EV
EV
Pinhole Dial
© 2008
Ralph W. Lambrecht
www.darkroomagic.com
f/stop
45
64
90
128
180
256
360
512
720
1k
2"
4"
8"
15"
30"
1'
2'
4'
8'
15'
30'
Time

Pinhole Dial assembled
(reduced view)


0
I
II
III
IV
V
VI
VII
VIII
IX
X
EV
EV
Pinhole Dial
© 2008
Ralph W. Lambrecht
www.darkroomagic.com
f/stop
45
0
64
-1
90
-2
128
-3
180
-4
256
-5
360
-6
512
-7
720
-8
1k
Time

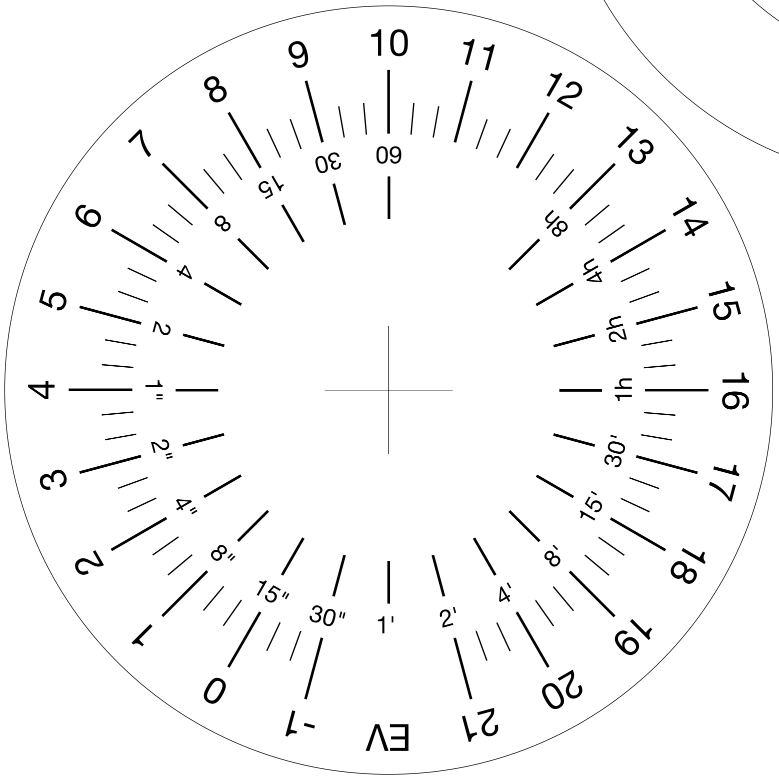

10
11
12
13
14
15
16
17
18
19
20
21
EV
-1
0
1
2
3
4
5
6
7
8
9
60
30
15
8
4
2
1"
2"
4"
8"
15"
30"
1'
2'
4'
8'
15'
30'
1h
2h
4h
8h

fig.20 The Pinhole Dial provides a visual reference to the way subject brightness will be represented in the pinhole print. Zone III and VII are marked to place shadow and highlight details, and the tonality extremes of Zone I•5 and VIII•5 are identified as black and white points. All scales are in standard shutter speeds, f/stops and EVs. Meter the subject values in EVs, and correlate them to the intended Zones on the dial. This will give you an overview of the subject brightness range and several exposure recommendations. However, potential reciprocity failure has not been accounted for.

# Drawing for Laser-Jig Housing

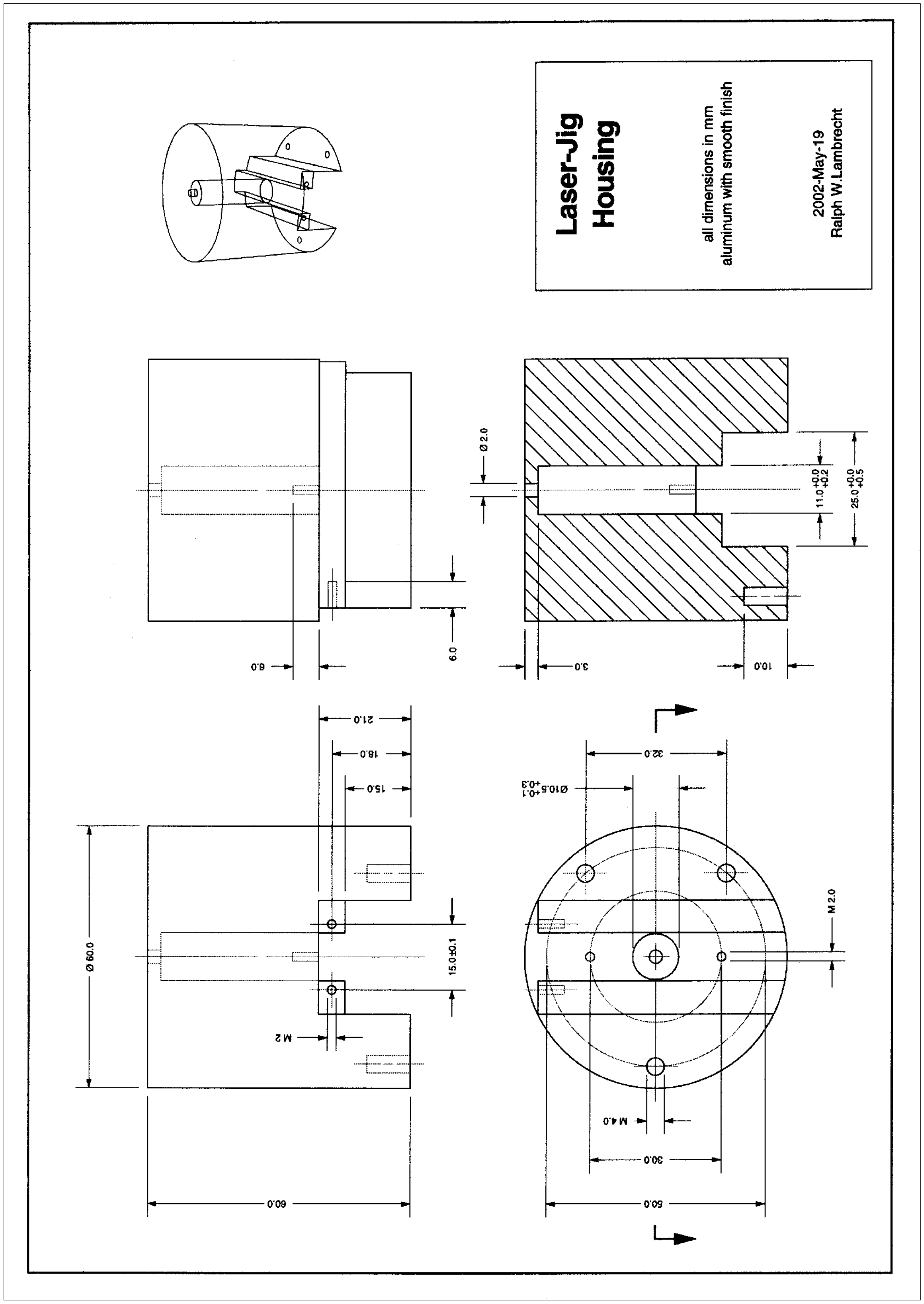

Laser-Jig Housing
all dimensions in mm
aluminum with smooth finish
2002-May-19
Ralph W.Lambrecht
Ø 2.0
11.0 +0.0 +0.2
25.0 +0.0 +0.5
6.0
6.0
3.0
10.0
21.0
18.0
15.0
Ø 60.0
15.0±0.1
M 2
Ø10.5 +0.3 +0.1
32.0
M 2.0
M 4.0
30.0
60.0
60.0

fig.21 With some ingenuity and help from a local machine shop, a do-it-yourself laser-alignment tool is brought from concept to reality. Three adjustable screws level the unit and align the laser module until it projects a perfectly vertical laser beam.

## Transfer Functions

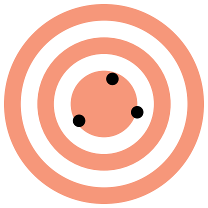
| **input** | target density curve '2.2c' | **output** at |
|---|---|---|
| 0% | 0.05 | |
| 5% | 0.11 | |
| 10% | 0.16 | |
| 20% | 0.27 | |
| 30% | 0.38 | |
| 40% | 0.49 | |
| 50% | 0.62 | |
| 60% | 0.77 | |
| 70% | 0.96 | |
| 80% | 1.20 | |
| 85% | 1.36 | |
| 90% | 1.55 | |
| 95% | 1.79 | |
| 98% | 1.96 | |
| 100% | 2.10 | |

| **input** | target density curve '2.2a' | **output** at |
|---|---|---|
| 0% | 0.05 | |
| 5% | 0.11 | |
| 10% | 0.16 | |
| 20% | 0.27 | |
| 30% | 0.38 | |
| 40% | 0.51 | |
| 50% | 0.66 | |
| 60% | 0.83 | |
| 70% | 1.04 | |
| 80% | 1.30 | |
| 85% | 1.45 | |
| 90% | 1.63 | |
| 95% | 1.84 | |
| 98% | 1.99 | |
| 100% | 2.10 | |

fig.22 The purpose of a transfer function is to bring the subjective tone-reproduction cycle full circle, and closely match the final print to the on-screen image. To do so, a transfer function must correct for the differences between the actual and the desired process characteristics. These are listed as absolute target densities for two different rendering intents. Target density curve '2.2a' (left) is designed for normal processing with normal shadow detail, followed by moderate archival toning. Target density curve '2.2c' (far left) compensates for heavy toning or provides emphasized shadow detail. Once collected, the input and output values are entered into the 'Curves' adjustment dialog box of your photo editing software and saved as a transfer function for future use.

# Glossary

## Photographic terms used in this book, and what we mean when we use them



### accuracy

is a measure of closeness to an accepted target value and indicates the proximity to that value. The closer a measurement is to the target value, the more accurate it is considered to be. A measurement can be accurate but not precise. *(see precision)*

### analog photography

is a chemically based imaging process in which light is directed onto a light-sensitive emulsion to create a latent image, which is subjected to subsequent processing steps, making it visible and insensitive to light. This was the dominant form of photography for much of its history, but is now supplemented by digital photography. *(see digital photography)*

### art

is the conscious expression or application of creative human skill and imagination, producing aesthetic work, primarily appreciated for its beauty or emotional power by a group of people. *(see fine art)*

### brightness

is a subjective sensation to luminance and cannot be measured, but it can be approximated by psychological scaling procedures. *(see luminance)*

### density

is a logarithmic measure of light transmission and reflection in negatives and prints. As a convention for this book, we have used 'relative' transmission and 'absolute' reflection densities, unless otherwise stated.

### digital imaging

describes the digital workflow, including digital image capture, manipulation, compression, storage, printing and display. *(see digital photography)*

### digital photography

is one of several forms of digital imaging in which light is directed onto a light-sensitive image sensor and recorded as a digital file for further processing. This book considers it as a supplement to analog photography. *(see digital imaging and analog photography)*

### emulsion

in silver-gelatin photography, the emulsion is a light-sensitive layer of silver-halide crystals, suspended in gelatin and coated onto a substrate of glass, plastic film, resin-coated or fiber-base paper. *(see film)*

### film

is a thin flexible strip or sheet of plastic, coated on one side with a light-sensitive emulsion for exposure in a camera and subsequent development into one or several negatives. *(see negative)*

### fine art

is crafted with the highest level of skill and experience and is primarily appreciated for its creative, imaginative and aesthetic value. *(see art)*

### gradation

refers to the change of image tones in images, negatives and prints. *(see tonality)*

### illumination

is the light falling onto a surface, and its intensity can be objectively measured as illuminance (lux or lm/m$^2$) with an 'incident' lightmeter. *(see lumination)*

### image

is a visual representation of an object, scene or person. An image can be seen on a ground-glass, captured on film, viewed in a negative, projected onto a surface, or it can be produced on photographic paper to create a specific print, but it can never be touched, because it is a 'only' a visual sensation. *(see paper and print)*

### lumination

is the light emitted or reflected from a surface, and its intensity can be objectively measured as luminance (nits or cd/m$^2$) by a 'reflected' lightmeter. *(see brightness and illumination)*

### monochrome

refers to any B&W or single-color image or print, including toned silver-gelatin and alternative-process prints, such as albumen, carbon, gum, oil, platinum, palladium or Cyanotype printing.

### negative

is an exposed and developed photographic image, recorded on film or coated glass, showing light and shadow values reversed from the original scene to produce print positives. The negative is an intermediate product of the traditional, analog photographic process. *(see film)*

### paper

is a term used throughout the book as an abbreviation for 'photographic paper'. It describes a material and is not directly related to a particular image or print. For example, the term 'paper contrast' is used to describe an image-independent material characteristic. *(see image and print)*

### photography

is an imaging process through 'painting' with light. Light, reflected or emitted from objects, is captured by the photographic lens of a camera, where the resulting information is recorded by a light-sensitive medium. *(see analog and digital photography)*

### pictorial range

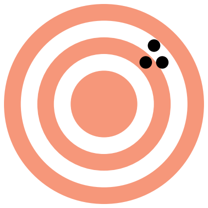
is a term used in the Zone System to describe a seven-zone tonal range, including all image tones of pictorial value, from the beginning of Zone II to the end of Zone VIII. *(see textural range)*

### pixel

is the smallest item of information (picture element) in a digital image, containing luminance and color.

### precision

is a measure of reproducibility or repeatability independent of the closeness to an accepted target value. The closer a number of measurements are to each other, the more precise they are considered to be. A measurement can be precise without being accurate. *(see accuracy)*



### print

is a term used throughout the book as an abbreviation to identify a unique photographic print. It describes the final object of the photographic process, which you can see and hold in your hand, and it is directly related to a particular image. For example, the term 'print exposure' can be used to describe an image-dependent requirement. *(see image and paper)*

### quality

describes the state of performing as intended, within identified specifications, while fulfilling customer expectations. A high-quality image, for example, renders a scene as expected with brilliant highlights, clear separation and good contrast throughout the midtones, and open, but dark, shadows. A high-quality print, on the other hand, does not fade or change tonality during its expected life span.

### subject brightness range

is a term is used throughout the book to describe a range of measurable light intensities. Strictly speaking, this is not correct, because brightness only refers to the human perception of luminance and not the measurable quantity of it. The term 'subject luminance range' is technically more accurate, but it is not frequently used in photographic literature. To avoid confusion, the incorrect, but more generally understood, term and its abbreviation, SBR, is used instead.

### textural range

is a term used in the Zone System to describe a six-zone tonal range, including all image tones having definite qualities of texture and the recognition of substance, from the center of Zone II to the center of Zone VIII. *(see pictorial range)*

### tonality

refers to the range of image tones in images, negatives and prints. *(see gradation)*

The purpose of this small glossary is to define our understanding and usage of a few photographic terms, as they appear throughout the book. We also want to make sure that some common terms are not confused with each other. This is not a claim for the actual or 'true' meaning of these terms, nor do we wish to challenge someone else's understanding of them. We merely offer an explanation of what we meant when we used them.

# Bibliography

## Reading suggestions

There is a wealth of photographic information available today, and many of these technical publications were an invaluable resource for our own studies and led to the preparation for this book. Unfortunately, some of these books are out of print with no plans for additional publication. However, you should have no problem finding them in good libraries or through out-of-print book searches. This bibliography is an inventory listing of the most valued pieces in our private libraries, and our recommendation for further reading in selected technical subject areas. Nevertheless, do not underestimate the value of non-technical 'picture books', because studying the work of other photographers is a great source of inspiration. Art is not created by technical skill alone, and imagination and creativity without proficient craftsmanship may leave the creation of an aesthetic photograph to pure chance. When the craft becomes second nature, we are free to concentrate on imagination and creativity.

### General Photography

Michael R. Peres, *The Focal Encyclopedia of Photography,* Focal Press, 2007
This 4th edition of the well-known classic, first published in 1956, is a thought-provoking and dynamic series of essays, chronicling the evolution of silver-halide photography, the birth of digital technologies, the contemporary issues in the world of image making, and the people who have made it happen.

Ralph E. Jacobson, *The (Ilford) Manual of Photography,* Focal Press, 2000
The 1st edition of this book was published in 1890. Starting with the 6th edition in 1970, the name 'Ilford' was dropped from the title. Now in its 9th edition, the book is a thoroughly reliable resource, offering a most comprehensive explanation of the essential principles of silver-based photography.

Michael Langford, *Basic Photography,* Focal Press, 1997
This is a recommended textbook for photography courses in Europe and assumes no prior knowledge of photography. It has sold millions of copies and has been updated regularly to account for improvements in cameras and film.

Michael Langford, *Advanced Photography,* Focal Press, 1998
This is the companion volume to the previous book, covering color and digital photography. It also provides information to the more advanced student or serious amateur, while still being practical and easy to understand.

Barbara London & John Upton, *Photography,* Addison-Wesley, 1989
This is a recommended textbook for photography courses in the USA and also assumes little prior knowledge of photography. It is comprehensive, well-illustrated and easy to read, covering all aspects of photography.

Marvin J. Rosen & David L. DeVries, *Photography,* Wadsworth, 1993
Complete and comprehensive, this classic guide is written for beginners as well as for more advanced photographers. In addition to the fundamentals, the book also covers the history of photography.

## Camera Techniques

Ansel Adams, *The Camera,* Little, Brown & Company, 1980
This is the first book of a three-volume set, written by an undisputed master of B&W. He has produced some truly memorable images and taught us how to get the most from negative and print, but here, he explains the fundamentals of image recording equipment.

Eastman Kodak Company, *Large-Format Photography,* Kodak Publication O-18e, 1995
This book is a beautiful introduction into the world of large-format photographs, which are often admired for their superior clarity, sharpness, exquisite tonal range and richness of detail.

Leslie D. Stroebel, *View Camera Techniques, 6th Edition,* Focal Press, 1993
This is a unique and comprehensive book, specializing in exploring the features, operation and application of view cameras. It also provides invaluable insight into view camera movement and general image formation, which are also useful to users of smaller film formats. A feature comparison of available view cameras is included.

W. F. Berg, *Exposure,* Focal Press, 1971
This out-of-print and slightly dated book is the 4th edition and a key volume of the highly respected 'Focal Manuals of Photo Technique' series. The book provides an understanding of the theory as well as the practice of exposure and is essential to all who use photography as a purposeful tool, rather than casual occupation. It will very adequately serve as a unique compendium of essential information to all those who prefer a single volume to a whole shelf of books.

J. F. Dunn and G. L. Wakefield, *Exposure Manual,* Fountain Press, 1981
This is the 4th edition of a book recognized as a standard text on the subject of camera exposure determination. It is an invaluable reference to all photographers, from keen beginner to advanced amateur, and embraces solutions to almost any exposure problem arising in practical photography. This book is also a great guide for complex lighting situations when straightforward metering alone is not good enough.

Harold M. Merklinger, *The Ins and Outs of Focus,* 1992
Mastery of the imaging process is the subject of this self-published book. It is not easy to read or understand but gives an interesting alternative point of view, supported by mathematical evidence.

Harold M. Merklinger, *Focusing the View Camera,* 1993
This is another book specializing on large format view camera movements. It contains the best explanation of the well-known 'Scheimpflug Principle' we have seen, and the author rediscovered Scheimpflug's 'Hinge Rule', giving the technique a more solid foundation.

## Art, Perception, Composition and Lighting

David Bayles and Ted Orland, *Art & Fear,* Capra Press, 1993
This book is a light but serious exploration of the way art gets made, the reasons it often doesn't get made, and the nature of the difficulties that cause so many artists to give up along the way. This book is about finding your own work and putting choice over chance.

Susan Sontag, *On Photography,* Farrar, Straus and Giroux, 1977
The book is a critical analysis of the profound changes photography has made to the way we look at the world since its invention. It raises important questions about photography and the people who practice it and establishes a much-needed consciousness about image making.

Nicolas Wade and Michael Swanston, *Visual Perception,* Routledge, 1991
The authors start from the basis of what function vision serves with object recognition being at the core of the book, while trying to answer the following questions: Does the world appear the same to everyone? Does what we know determine what we see?

Richard L. Gregory, *Eye and Brain,* Princeton University Press, 1997
Since its 1st edition in 1966, this book has established itself worldwide as an essential introduction to the basic phenomena of visual perception. It offers a clear description of how we see brightness and objects, and explores the area of visual illusion to explain how perception works and why it sometimes fails.

William Mortensen, *The Command to Look,* Jacques de Langre, 1967
This is an extremely valuable, but unfortunately also a very expensive, out-of-print book. In it, the author shares his unique and effective way of composing successful and powerful images. If you looked for solid advice on composition, you will find it in this book.

Eastman Kodak Company, *Professional Photographic Illustrations,* Kodak Publication O-16, 1989
This book is a beautiful introduction into successful lighting techniques for product and tabletop photography.

William Mortensen, *The Model,* Camera Craft Publishing, 1948
There are a number of books available illustrating how to pose a model, but you will struggle to find one approaching the subject in such an organized manner. Also covered is appropriate clothing, make-up and how to provide proper direction to the model. This book is highly recommended for all model and portrait photographers.

Roger Hicks and Chris Nisperos, *Hollywood Portraits,* Amphoto, 2000
Effective portrait lighting is learned by studying successful examples. In this book, the authors explore how the 'Hollywood Look' was created

and how it can be recreated today, by analyzing the actual lighting plans and techniques of the original portraits. Over fifty photographs are examined, revealing information on film, camera, props and poses.

Mark A. Vieira, *Hurrell's Hollywood Portraits,* Harry N. Abrams, 1997
This book presents in depth the work of George Hurrell, the photographer who, more than anyone else, was responsible for developing the 'Hollywood Glamour Portrait'. The author explains in detail Hurrell's approach to 'beauty' lighting and other lighting techniques.

## Monochrome Photography

Henry Horenstein, *Black & White Photography,* Little, Brown and Co, 1983
This is a very sound book for beginning B&W photographers from a teaching professional who has the talent to concentrate on the basics and produce a clear and concise book, which many consider to be one of the best manuals of its kind.

Henry Horenstein, *Beyond Basic Photography,* Little, Brown and Co, 1977
This book answers the more technical questions of photographers who are already familiar with the basics. It provides the reader with control over the entire photographic process from exposure to final print.

David Vestal, *The Craft of Photography,* Harper & Row, 1974
This is the most comprehensive guide to B&W photography on our shelves. It is a complete overview on equipment, materials, exposure, development and printing, with practical advice on darkroom setup.

C. I. Jacobson and R. E. Jacobson, *Developing,* Focal Press, 1972
This out-of-print and slightly outdated book is the 18th edition and another key volume of the highly respected 'Focal Manuals of Photo Technique' series. The book deals in detail with the action of the various components of the developer, which will produce the required results. It lists nearly three hundred recommended formulae and gives fifty compact comparative tables.

Jack H. Coote, *Ilford Monochrome Darkroom Practice,* Focal Press, 1996
This book covers the breadth of monochrome work, including professional applications and equipment. Although it centers on Ilford products, it discusses many aspects of technique during exposure, development and printing. It contains many useful hints and tips for getting the most from film and chemistry.

Barry Thornton, *Elements*, Creative Monochrome, 1993
Subtle pictures together with a non-technical explanation of the Zone System and the author's emotional response to picture taking make this book one of the few that can be read like a novel. It uses a trail of pictures to map the author's quest for the ultimate in equipment and materials.

Barry Thornton, *Edge of Darkness*, Argentum, 2000
This is a unique monochrome photography book. While most counsel the virtues of image manipulation, the author argues for the virtue of image sharpness. It takes the reader step-by-step through the process of releasing the power and satisfaction of high definition photography.

Arnold Gassan and A. J. Meek, *Exploring Black and White Photography*, Wm. C. Brown Communications, 1993
In its 2nd edition, this text deals exclusively with B&W photography. The authors illustrate how B&W offers more creative freedom than color, separating us from reality and letting our eyes explore the abstraction of form, while discovering visual analogies all too easily hidden by color.

Stu Williamson, *Concept to Print*, Argentum, 1998
The backbone of this book is the experience and the skill of this author. He explains his reasons for choosing a specific technique and provides a unique insight into his approach for the making of twenty photographs. This includes the source of the inspiration, the initial plan for creating the image and the lighting, camera and darkroom techniques used.

George E. Todd, *From Seeing to Showing*, Argentum, 2001
In this book, the author discusses the inspiration for twenty photographs and how they were produced. The reader is guided through the camera and darkroom techniques used with a series of illustrated instructions. The importance of composition, highlights and shadows, and dealing with difficult negatives are clearly explained.

Hugh Milsom, *Infra-Red Photography,* Fountain Press, 2001
There is an air of mystique surrounding infrared photography. Its special effects offer the creative photographer a great number of possibilities. This book covers all aspects of infrared photography and contains a step-by-step guide for the beginner, starting with exposing and developing the very first roll of film.

## Sensitometry and Zone System

Eastman Kodak Company, *Basic Photographic Sensitometry Workbook,* Kodak Publication H-740, 2006
This highly recommended introduction to sensitometry is provided for free on the company's website. It is a valuable publication and was written in a programmed instruction format, which allows students of sensitometry to study, learn and verify at their own pace.

Jack Eggleston, *Sensitometry for Photographers,* Focal Press, 1984
This well-organized book is addressed at experimentally minded photographers who wish to achieve superb image quality through careful technique. It deals with the principles and application of sensitometry, progressing gradually from the basic to the more advanced.

Hollis N. Todd and Richard D. Zakia, *Photographic Sensitometry,* Morgan & Morgan, 1969
This book has a scientific approach to sensitometry and is over our heads in many areas, but it has clarified and simplified many things for us. It gave us a better understanding of the underlying principle of the Zone System and has an excellent chapter on reciprocity failure.

Ansel Adams, *The Negative,* Little, Brown & Company, 1981
This is the definitive text on the Zone System and a must-read for monochrome photographers. Apart from the technical aspects of the Zone System, this book also explores the seminal concept of visualization in B&W photography using many examples of his work.

Chris Johnson, *The Practical Zone System,* Focal Press, 1994
This pleasantly simplified guide to Ansel Adams's Zone System does not miss the point. You will not become a Zone-System expert from reading this text, but you will gain a solid understanding of fundamental principles. Included are the author's test results for many film/developer combinations as a starting point for your own work.

Minor White, Richard Zakia and Peter Lorenz, *The New Zone System Manual,* Morgan & Morgan, 1976
This booklet continues where Ansel Adams left off the Zone System explanation. It is the most extensive book on the system as far as we know, while still understandable for anyone seriously exploring B&W photography. However, we much prefer Phil Davis's method of film testing to the one proposed here.

Phil Davis, *Beyond the Zone System,* Focal Press, 1993
Now in its 4th edition, this valuable book is filled with material and equipment tests to obtain the best results in B&W work. Starting with the basics, it moves on to complex sensitometry and material evaluation. We don't agree with the Zone System mathematics introduced by this book, but to understand the science behind the Zone System, you can't avoid this highly recommended book.

William Mortensen, *Mortensen on the Negative,* Simon and Schuster, 1940
This out-of-print and slightly out-of-date book still makes for a very interesting read. It was written around the same time Ansel Adams developed his Zone System, and this explains why one finds amazing parallels between the two techniques.

## Photographic Optics, Chemistry and Processing

Henry Dreyfuss, *The Measure of Man,* Whitney Library of Design, 1967
The author conducted ergonomic studies, and the results are used by product designers in all fields. The studies concerned with the limits of human vision are valuable to the discriminating printer.

Graham Saxby, *The Science of Imaging,* IOP Publishing, 2002
This introduction is essential reading if image science plays an important part in your photography, or if you are wishing to know more about the underlying principles of image making. The author's approach is friendly and direct, with numerous marginal notes that illuminate particular aspects of the subject or give brief biographical backgrounds of the pioneers of various techniques who may otherwise remain only names.

John B. Williams, *Image Clarity,* Focal Press, 1990
This is an exhaustive investigation into the subject of high-resolution photography and image definition. This book appeals first to the more technical-minded photographer, but its careful explanations and helpful illustrations provide fundamental knowledge for all.

Arthur Hardy and Fred Perrin, *The Principles of Optics,* McGraw-Hill, 1932
This reference book is the result of extensive experience in teaching optical principles at MIT. It is written for optical engineers, but the chapter covering the function of the human eye will be of great interest to all serious photographers and printers.

Eastman Kodak Company, *Kodak Filters,* Kodak Publication B-3, 1981
This book is for scientists whose use of filters requires extensive spectrophotometric data. However, the graphical representation of light transmission clearly illustrates filter functionality to all.

George T. Eaton, *Photographic Chemistry,* Morgan & Morgan, 1988
This is the 4th edition of a photographic chemistry book that was exclusively written for the non-chemist. It is not a source for chemical formulae but a must-read for everyone who wants to understand them.

Steven G. Anchell, *The Darkroom Cookbook,* Focal Press, 2008
For those who wish to experiment with self-made chemistry, or understand how it works and can be improved, this is the reference book. Now in its 3rd edition, it contains many useful tips, formulae and hints on photochemistry and unravels the black art of making your own.

Steven G. Anchell, *The Film Developing Cookbook,* Focal Press, 1998
This book will help photographers to acquire a working knowledge of photographic chemistry, relevant to B&W film developing, and it will serve as a reference and refresher for photographers at all skill levels.

E. J. Wall, Franklin I. Jordan and John S. Carrol, *Photographic Facts and Formulas,* Amphoto, 1975
This out-of-print book is probably one of the oldest photographic compendiums in active use. First published in 1903, it has been revised several times since, and with minor exceptions, the information and chemical formulae provided are still up to date. The book covers photographic processing to a level of detail typically not found in other books.

Grant Haist, *Modern Photographic Processing,* John Wiley & Sons, 1979
This rare two-volume book was reprinted by the author in 2000. It was part of the publisher's 'photographic science and technology series' and contains everything one needs to know about photographic chemistry, emulsions and processing. The entire photographic process is explained, in unparalleled detail, from the atomic basis of photography to making the image permanent. For the practicing photographer, the text is supported by chemical formulae throughout the book.

C.E. Kenneth Mees and T. H. James, *The Theory of the Photographic Process,* The Macmillan Company, 1966
This classic reference book is a collection of technical articles, providing a general handbook of photographic processes. The bibliographies at the end of each chapter allow for extensive research. It is not an easy read, but you will always find clear and useful information in it.

T. H. James and George C. Higgins, *Fundamentals of Photographic Theory,* Morgan & Morgan, 1968
This highly technical book gives a general account of the theory of the photographic process based on fundamental chemical and physical concepts. It is for those interested in advanced treatment of subjects not covered to this level of detail in other publications.

Thomas Woodlief, Jr., *SPSE Handbook of Photographic Science and Engineering,* John Wiley & Sons, Inc., 1973
This reference book reminds us of many things previously learned but not regularly used. In 1,400 pages, compiled by over 100 contributors, it provides very technical information about any possible aspect of photography. The book is directed at the experienced, practicing engineer and scientist. Almost every section of the book contains tutorial material but not enough for the beginner to learn an unfamiliar field.

## General Printing

Ansel Adams, *The Print,* Little, Brown & Company, 1983
This is the third book in the famous series. Many value this book to define printing techniques, standard print finishing and presentation practice. Discusses darkroom design, equipment, print processing and sensitometry. This book proves that the 'perfect negative' is only the starting point for the 'perfect print'.

C. I. Jacobson and L. A. Mannheim, *Enlarging,* Focal Press, 1975
This out-of-print but mostly up-to-date book is the 22nd edition and another key volume of the highly respected 'Focal Manuals of Photo Technique' series. It covers the entire spectrum of enlarging and ranges from fundamental considerations, negative quality and principles of enlarging and darkroom equipment to different systems of exposure measurement and special processing.

Eastman Kodak Company, *Quality Enlarging,* Kodak Publication G-1, 1995
This book is a beautiful introduction to darkroom design, and concentrates on quality print making, retouching and getting the final print ready for presentation and display.

David Vestal, *The Art of Black-and-White Enlarging,* Harper & Row, 1984
This is a book no B&W worker should be without. The author works through advanced techniques and subjects with a no-nonsense approach, while presenting difficult material in palatable form. It is filled with the author's experience and practical test proposals to gain your own.

Carson Graves, *Black-and-White Printing,* Focal Press, 2001
This is an easy to understand book for beginning to intermediate darkroom workers. It introduces the reader to darkroom exposures and proper paper-contrast selection. In addition to explaining the procedures, this valuable book contains exercises that help the reader to learn with his own equipment and materials.

Steve Anchell, *The Variable Contrast Printing Manual,* Focal Press, 1997
This book is a comprehensive resource for photographers printing with variable-contrast papers. The author provides a wealth of information about a medium that now dominates B&W printing.

Richard J. Henry, *Controls in Black and White Photography,* Focal Press, 1986
The author uses his scientific training as a medical doctor to expose a few photographic myths. The book concentrates on B&W printing and kills many dubious doctrines supported by other photographic writers. His exhaustive tests save us all many laborious tasks. Visit your local library, because it is unfortunately out of print.

Howard Bond, *Numerous Articles on Quality Black and White Camera, Zone System and Printing Technique, Photo Techniques* magazine, 1985 - 2001
This collection of articles would make a fabulous book by itself. The author, an excellent photographer, printer and educator, shares decades of experience and valuable advice in easy-to-understand chunks.

John Sexton, 'The Expressive Black and White Print', *Apogee Photo* magazine, 1990
In this electronic magazine article, a well-respected photographer, who was darkroom assistant to Ansel Adams, uses one negative to show a basic but systematic and sophisticated approach to B&W printing.

Larry Bartlett and Jon Tarrant, *Black and White,* Fountain Press, 1996
Larry Bartlett was a professional printer. The book explains how he produced involving, expressive prints from other people's negatives. The

preliminary chapters look at the basics of darkroom design and equipment and the book then moves on to explain how each of the featured prints was coaxed from the negative.

Tim Rudman, *The Photographer's Master Printing Course,* Mitchell Beazley, 1994
This book is a great reference for down-to-earth printing techniques. Starting with the basics, it also covers numerous methods of creative print manipulation and toning, amply illustrated.

Les McLean, *Creative Black & White Photography,* David & Charles, 2002
The author combines his technical expertise with inspiring images to take the reader step by step through the thought processes and technical procedures involved in producing high-quality images. At the core of this comprehensive guide is the belief that it is impossible to separate picture-taking from print-making.

Eddie Ephraums, *Gradient Light,* Working Books, 1994
This book is recommended as a refreshing alternative for the all-too-serious Zone System worker. The images presented are all made with trade-processed chromogenic film, but the author combines it with creative printing techniques and common VC papers to stunning effect.

Ctein, *Post Exposure,* Focal Press, 2000
Distilled from over 30 years of experience, this practical how-to book is filled with valuable technical analysis. The experiments and results discussed are of importance to serious B&W and color darkroom enthusiasts.

Veronica Cass, *Retouching,* VC Publishing, 1992
This book covers retouching from start to finish. It begins with retouching the negative and following through to the print. Sometimes, this means restoring a photograph, airbrushing a background or applying any number of techniques to achieve a professionally finished print.

William Mortensen, *Print Finishing,* Camera Craft Publishing, 1938
This old, out-of-print but extremely valuable book covers the unique abrasion-tone technique, developed by the author. More importantly, though, it also gives up-to-date advice on how to position and orient a print aesthetically on the mount-board.

## Specialist Printing

Tim Rudman, *The Master Photographer's Toning Book,* Argentum, 2002
This book describes entry-level and advanced toning techniques for archival processing and creative image manipulation, with a chapter devoted to each toner. It also covers negative toning, selective toning and less conventional materials, such as tea and coffee. This book is an invaluable reference for anybody toning their negatives and prints.

Eddie Ephraums, *Creative Elements,* Fountain Press, 2000
This book shows the transformation of some seemingly ordinary negatives into wonderfully moody images. It provides excellent examples of print manipulation and toning. While the images cover a breadth of techniques, they all clearly reflect the author's personal style. For this book, he has selected a series of prints to demonstrate his techniques.

Tim Rudman, *The Master Photographer's Lith Printing Course,* Argentum, 1998
The book is an in-depth guide, filled with many practical examples and tips on making lith prints. It covers the subject fully and at every level and quickly developed into a standard text. It is hard to see why anyone else would have to write another book on this subject.

Tony Worobiec and Ray Spence, *Beyond Monochrome,* Fountain Press, 1999
The book explores the use of alternative processes to create unique, evocative images of those two photographic magnets, the human form and dereliction. It is a practical book, explaining hand tinting, toning and airbrushing, as well as some historic techniques.

Randall Webb and Martin Reed, *Spirits of Salt,* Argentum, 1999
The book gives detailed introductions to alternative photographic processes while featuring the work of established artists. It is a practical darkroom manual, convincingly examining each process in its own right, giving a historical overview of each process, and supplying a shopping list to identify the key materials needed, before taking the reader, step-by-step, through the process.

## Digital and Hybrid Imaging

Dan Burkholder, *Making Digital Negatives,* Bladed Iris Press, 1999
This is a highly recommended, must-have book for photographers who want to combine the beauty and permanence of traditional fine-art printing processes with the power and precision of digital imaging. In this 2nd edition of the book, the author shares his fine-art and digital expertise to bridge the worlds of traditional and digital image making.

Ron Reeder and Brad Hinkel, *Digital Negatives,* Focal Press, 2007
This book bridges the world between digital photography and alternative analog printing. It uses digital inkjet negatives to get you from the monitor, through an inkjet negative to alternative processes like palladium printing, for which inkjet negatives provide sufficient quality.

Martin Evening, *Adobe Photoshop for Photographers,* Focal Press, 2001
Many regard this frequently updated book as the most useful Photoshop text for practical photographers. It includes many examples, hints, tips and tutorials on CD, going far beyond the standard Photoshop handbook, covering all the most-useful features in understandable terms.

Katrin Eismann, *Photoshop Restoration & Retouching,* Que, 2001

This book is an ideal manual to guide the modern photographer in making subtle and meaningful improvements to digital images. While it concentrates on restoring aged or damaged photographs, the presented techniques are equally applicable to optimize contemporary prints.

## Archival Processing

Laurence E. Keefe Jr. and Dennis Inch, *The Life of a Photograph,* Focal Press, 1984

This book covers the complete subject of image permanence from archival processing to film and print storage. It also discussed the differences between RC and FB prints, and explores the benefits and disadvantages of several print mounting materials and techniques. Valuable advice is given to plan and design professional exhibitions, and practical storage options for current film and print materials are covered in detail.

Archival processing is a changing and ever-expanding area of knowledge. Consequently, good books, such as the one above, which cover the entire subject are rare and difficult to keep up-to-date. What follows is a list of technical papers and electronic articles, which we feel have the best-researched and most-current information.

James M. Reilly, Douglas W. Nishimura, Kaspars M. Cupriks and Peter Z. Adelstein, 'Stability of Black and White Photographic Images', *The Abbey Newsletter*, Jul/1988

Douglas W. Nishimura, 'How Stable are Photos on RC Papers?', *The Abbey Newsletter*, Nov/1997

Michael J. Gudzinowicz, 'Post Development Processing', 1998

Martin Reed, 'Mystery of the Vortex', *Photo Techniques* magazine, Jul/Aug & Nov/Dec 1996

Richard Knoppow, *pure-silver@tundraware.com mailing list and rec.photo.darkroom newsgroup, additional private correspondence,* 1999-2001

## Historic Papers

At the end of the 19th century, Ferdinand Hurter and Vero Charles Driffield published the results of their photographic research. The importance of their findings was soon recognized, and their sensitometry methods became an industry standard. The following book is a collection of their most important papers, which are largely out-of-date and not applicable to modern emulsions, but they demonstrate the significance of their contribution to photographic science. The book also contains entertaining correspondence between the two scientists and one of their strongest critics, Captain W. Abney, which makes for a very interesting read.

W. B. Ferguson, *The Photographic Researches of Ferdinand Hurter & Vero C. Drieffield,* Morgan & Morgan, Facsimile Edition, 1974

In the first half of the 20th century further valuable in-depth photographic research was conducted. Among others, Loyd A. Jones and his colleagues at the research laboratories of the Eastman Kodak Company in Rochester, New York deserve major credit and respect for their contribution. He and his team published several historic papers of which a few are most important to this book. Despite its age, this research is largely up-to-date and still a milestone in the evolution of photographic science. Contact your local library to obtain copies of these most valuable papers.

Loyd A. Jones, 'The Evolution of Negative Film Speeds in Terms of Print Quality', *Journal of the Franklin Institute*, Mar/1939, Page 297 - 354

Loyd A. Jones and C. N. Nelson, 'A Study of Various Sensitometric Criteria of Negative Film Speeds', *Journal of the Optical Society of America*, Mar/1940, Page 93 - 109

Loyd A. Jones and H. R. Condit, 'The Brightness Scale of Exterior Scenes and the Computation of Correct Photographic Exposure', *Journal of the Optical Society of America*, Nov/1941, Page 651 - 678

Loyd A. Jones and C. N. Nelson, 'The Control of Photographic Printing by Measured Characteristics of the Negative', *Journal of the Optical Society of America*, Aug/1942, Page 558 - 619

Loyd A. Jones and C. N. Nelson, 'Control of Photographic Printing: Improvement in Terminology and Further Analysis of Results', *Journal of the Optical Society of America*, Nov/1948, Page 897 - 920

## Internet Newsgroups and Specialist Interest Sites

Many internet newsgroups and mailing lists specialize in B&W photography and darkroom technique. They provide the opportunity for a worldwide community of photographic enthusiasts to share their knowledge and experiences. Use your search engines and newsgroup listings to find the one best matching your interests.

At the time of this writing, the Analog Photography Users Group (APUG) is one of the most dynamic symposiums on the web. APUG has a diversified portfolio of analog forums and thousands of active members. It is an international community of like-minded individuals devoted to traditional (non-digital) photographic processes. You currently find them at: http://www.apug.org. We are looking forward to meeting you there!

# Index

**A**

aberration, lens 136, 138
accelerators 500
acid 499
acid fixer 36, 500, 504
acuity 7
acutance 139, 259
additive color system 159
adjust film development 198, 199, 243, 255
adjust print contrast 243, 299
after-treatment, negative 204
agitation, film development 196
Airy disc 137
alkaline fixer 36, 504
alternative processes 380
anatomy, human brain 8
anatomy, human eye 7
angle of view 151, 413
aperture accuracy 416
aperture values 491
archival framing 81
archival limits 39, 45, 201
archival mounting 57
archival processing 35, 194
archival research 51
archival storage 167
archival testing 38, 46, 50, 202
archival toning 39, 200
archival washing 45, 201, 451
arithmetic timing 24, 491
artistic evolution 15
ASA film speed 215
average gradient 195, 213, 220, 436
average gradient meter 221, 518
average gradient table 517

**B**

backboard, print 58
backlight, studio 365
banding, digital 124
base 499
base+fog density 195, 215, 220, 296, 303
Bayer array 159
bellows extension 192
bellows extension target & ruler 520
binary system 464
bit depth, digital 162
bleaching prints 343, 389
brain, human 8
brightness range 114, 115, 213
brightness ratio, subject 114, 115
buffers 501
burning card 477
burning mask 357, 396, 402
burning prints 33, 374, 378, 393, 477

**C**

C41 processing 247
C41 Zone System 246
Calgon 501
calibrating color enlarger 309
calibrating standard paper grades 302
Callier effect, coefficient 434
camera filter 190
camera flare 416
camera focusing 145, 148
camera formats 409
camera lenses 412
cameras 409
camera shake 419
cascade washing 202
characteristic curves 110, 120, 195, 492
  template, film 516
  template, paper 514
chemical formulae 502
chemical safety 502
chemical shopping list 502
chemistry 498
China ink 78
chromogenic film 246
circle of confusion 133, 445, 509
cleanliness, darkroom 426
close-up correction 192, 520
coin test, safelights 432
color
  additive system 159
  subtractive system 310
color conversion, digital 382
color enlarger, calibration 309
color sensitivity 7, 190, 429, 442, 486
combination toning 44
compounds 499
compression, digital 166
condenser enlarger 433
contact frame 455
contact printing 279, 483, 494
contraction development, film 197
contrast control 198, 239, 256, 263, 299, 309, 318, 324, 372, 398, 494
contrast control masks 263
contrast control nomograph 224
contrast, film 139, 195
contrast filter 190, 191, 304, 309
contrast, local 239
contrast measurement 221, 302, 307
contrast, overall 239
contrast, paper & print 28, 302
contrast standards, paper 302
converging lines, darkroom 446
copy negative 282
copy-print process 282
corner-mounting 71
correction curves, digital 494
craft & creativity 11
crisscross method 501
critical focusing 145
cutting film holders 464
cyanotype 380

**D**

darkroom cleanliness 426
darkroom design 421
darkroom, dry side 425
darkroom easel 455
darkroom equipment 438, 449
darkroom filter 304, 310, 429, 430
darkroom flashlight 457
darkroom focusing aid 443, 454
darkroom layout 422
darkroom lighting 424
darkroom, light proofing 422
darkroom, light-tight drawer 425
darkroom, light-traps 423
darkroom meter 452
darkroom plumbing 427, 451
darkroom, print evaluation 424, 425
darkroom, safelights 424
darkroom, safelight test 428, 432
darkroom safety 427, 502
darkroom sharpness 438
darkroom sink 426, 427
darkroom timer 452
darkroom torch 457
darkroom ventilation 423
darkroom, water temperature control 451
darkroom, wet side 425
decimal system 464
dedicated film backs 245, 395
densitometer 452
density 434, 493
  first usable, IDmin 303, 429
  last usable, IDmax 303, 429
density measurement 219, 434
density range 115, 196, 244, 296, 303
density standards 116, 507
depth of field 131, 354, 444
  hyperfocal distance 135, 354
depth-of-field equations 134, 444
depth-of-field markings 354
depth of focus 135, 444
depth-of-focus scale 136
deterioration, print 48
developer additives 500
developer aging 339

developer dilution 339, 342
developer exhaustion 342
developer formulae 503
developer ingredients 500
developer temperature 342
developing agents 500
development agitation 196
development control 197, 251
development correction 255
development deviation 198, 199
development evaluation 253
development, film 194, 197, 214, 225
development, print 35, 340
development records 480, 522
development temp compensation 197, 513
development temperature 196
development time 196
development variations 198, 199, 255, 340
dichroic filter, darkroom 310
differentiating print density 297
diffraction limits 136, 139
diffuse density & reflection 434
diffusion enlarger 433
digital banding 124
digital camera 158, 176
digital camera characteristic curve 112
digital camera histogram 161
digital camera resolution 172
digital camera sensor 158
digital color conversion 382
digital correction curves 494
digital dynamic range 164
digital histogram 161
digital image file formats 165
digital image gradation 124
digital monochrome 382
digital negative 275, 494
digital noise 160
digital photography 157
digital pinhole 153
digital posterization 124, 163
digital quality 170
digital resolution 171, 172,
 174, 176, 177, 279
digital resolution limits 161, 176
digital resolution requirements
 171, 174, 176, 177
digital sensitometry 112
digital sharpening 165
digital speed 160
digital storage 167
digital tonal control 161
digital tone reproduction cycle 119
digital transfer function 494, 527
digital unsharp mask 165
digital Zone System 107
diluting 501
direct toning 40
display lighting, print 296
Dmax, film 220
Dmax, paper 296, 303
Dmin, film 220
Dmin, paper 296, 303
dodge & burn prints 33, 243, 400
dpi, dots per inch 279
dry-down, print 347
drying film 204
drying prints 47
dry-mounting 58, 64, 66
dry side, darkroom 425
dual-filter method, VC printing 311
dust & scratches 79, 437
dynamic range 164, 170, 173

**E**

easel, darkroom 455
edge burning 27, 34
edge effect 139, 259
edition size, print 92
effective film speed 216, 220, 222
EI, exposure index 208, 215
electromagnetic spectrum 5
electronic flash 419
elements 498
emulsion 499
enlarger 309, 433, 444, 445, 510, 511
enlarger alignment 439, 440
enlarger calibration 309
enlarger easel 455
enlarger filter 310
enlarger focusing 442
enlarger heads 433
enlarger height compensation 448, 511
enlarger light sources 433
enlarger magnification 510
enlarger meter 453
enlarger stability 438
enlarger timer 452
enlarger types 433
enlarging lens 441
equilibrium, washing 202
evaluating prints 296, 424
EV, exposure value 186
evolution, artist 15
exhibiting prints 90, 296
expansion development, film 197
exposure 32, 161, 185, 187, 192,
 233, 329, 336, 414, 448, 466,
 468, 491, 511, 520, 525
exposure correction 192,
 254, 315, 448, 520
exposure correction table 317
exposure deviation 228
exposure evaluation 253
exposure index, EI 208, 215
exposure latitude 229
exposure masks 263
exposure meter 108, 190, 416, 468
exposure range, film 230
exposure range, negative 115
exposure range, paper 304, 515
exposure records 480, 522
exposure table, print 317
exposure target 192, 520
exposure timing 23, 186, 414, 492, 508
exposure value, EV 186
eye, human 6

**F**

factorial development 340
Farmer’s Reducer 205, 343, 505
FB, fiber-base paper 35
file compression, digital 166
file formats, digital 165
fill light, studio 365
film, average gradient 195, 213, 220, 436
film backs, dedicated 245, 395
film characteristic curve 111, 195, 516
film, chromogenic 246
film, contraction development 197
film contrast 195
film curve 111, 215, 220
film developer 503
film development 194, 197, 214, 225, 513
film development adjustment 197, 243, 255
film development evaluation 253
film development template 516, 518, 519
film development test 214, 216, 519
film, Dmin & Dmax 220
film drying 204
film, expansion development 197
film exposure 188, 216, 225, 231
film exposure correction 228, 254
film exposure evaluation 253
film exposure range 230
film fixer 504
film fixing 194, 200, 203
film flatness, darkroom 439
film formats 411
film grain 159, 209, 210, 249
film holder dimensions 146
film holder identification 463
film, infrared 369
film latitude 229
film overdevelopment 227, 228
film overexposure 226
film, overexposure 231
film plane 134
film pre-exposure 233
film processing 194, 247
film processing control 255
film processor 450
film reciprocity failure 187
film resolution 208, 209
film resolution requirement 133, 509
film scanner 175
film sensitivity 491
film sharpness 208, 209
film, spectral sensitivity 190
film speed 208, 209, 215, 222, 250, 491
film speed point 213
film speed test 216
film stabilization 203
film standard 211, 215, 220
film storage 206
film template 516, 518, 519
film testing 214, 216, 519
film thickness 146
film toning 200
film underdevelopment 227, 228
film underexposure 226
film, underexposure 231

filter, camera 190
filter, darkroom 304, 310, 429, 430
filter, dichroic 310
filter factors 191
filter numbers 304
fine-tuning print exposure & contrast 295
first usable density, IDmin 303, 429
fixed-contrast paper 28
fixer additives 500
fixer capacity, prints 39
fixer formulae 504
fixer ingredients 500
fixer, rapid 36
fixer strength 37
fixer test solution 505
fixing agents 500
fixing film 194, 200
fixing, optimum time 38
fixing prints 36
fixing process 37
fixing test, film 203, 505
fixing test, prints 38, 505
fixing time, optimum 38
fixing time, prints 37
flare test 416
flash, electronic 419
flashing prints 329, 456
flashlight, darkroom 457
flash triggering 419
flatbed scanner 176
focal-length assessment 413
focal plane 134
focus error 148
focus finder, darkroom 443, 454
focusing aid, darkroom 443, 454
focusing, camera 145, 148
focusing, darkroom 443, 454
focusing, enlarger 442
focus target 148
fogging prints 329
formulae, chemical 502
framing prints 81
framing techniques 84
Fresnel lens 147
f/stop, definition 491
f/stop timer 453, 454
f/stop timing 23
f/stop timing table 26, 508

**G**

gamma 195, 213, 436
geometric timing 25, 491
glass cleaning 84
glazing prints 82
gold toning 44
gradation, image 120, 124
graded paper 28
gradient, negative 195, 213, 436
grain, film 159, 209, 210, 249
grain focuser 443, 454
gray card 105, 252
ground-glass position 146
gum print 381

**H**

halftone negative 275, 288
halftone pattern 280
halftone printing 275
hardeners 500
height compensation, enlarger 448, 511
high-contrast scene 198, 236, 240, 372, 396, 402
high dynamic range, HDR 164
highlight contrast 195
highlight control, print 266, 270, 327, 332, 343, 347, 357, 378, 389, 477
highlight discrimination 297
highlight exposure, print 32
highlight gradient 195
histogram, digital 161
historic processes 380
human brain 8
human eye 6
human vision 6
human vision limits 131, 297
human visual system 9
hybrid printing 275
hybrid scanner 176
hyperfocal distance 135, 354
hypo-clearing agent 45, 504
hypo estimator 46, 505
hypo test 46, 203, 505

**I**

identification, film holder 463
identification, negative 463, 482
identification, print 71, 75
IDmin & IDmax, paper 303, 429
illuminance 185, 186
illumination, enlarger 435
image clarity 139, 140
image contrast 139
image file formats, digital 165
image formation 150
image gradation 120
image gradation, digital 124
image identification 482
image magnification 134, 191
image paths 129
image permanence 50
image quality 17, 225, 231
imagesetter 278
image stabilizer 47, 203
incident light 186
incident lightmeter 417
India ink 78
indirect toning 40
infrared film 369
infrared radiation 6
inkjet characteristic curve 112
inkjet negative 288
inorganic compound 499
intensification, negative 205
inverse-square law 448
ISO film speed 215
ISO film standard 215
ISO paper grades 298, 303, 309, 515
ISO paper standard 296, 303

**K**

key light, studio 365
kicker, studio lighting 365
Kodak Gray Card 105, 252

**L**

large-format cameras 410
laser alignment tool 440, 526
last usable density, IDmax 303, 429
latent image stability, paper 339
latitude, film 229
leaf shutter 415
lens aberration 136, 138
lens, angle of view 151, 413
lens aperture 491
lens, camera 412
lens diffraction 138
lens, enlarger 441
lens extension 191
lens flare 416
lens, focal length 413
lens, Fresnel 147
lens resolution 132, 138
lens testing 132
life expectancy, media 167, 201
light, definition 6
lighting conditions, display 296
lighting, darkroom 424
lighting portraits 365
lighting ratio 114, 115
lighting shiny objects 362
lighting, studio 365
lighting, three-point 368
lightmeter 416
lightmeter flare 416
light metering 108, 416
lightmeter, spectral sensitivity 190
lightmeter, zone dial 468
light painting 376
light proofing, darkroom 422
light-tight drawer, darkroom 425
light transmittance 83, 493
light-traps, darkroom 423
light value, LV 187
liquid light 343, 389
litmus test 499
local contrast 239
logarithms 491
long-focus lenses 413
low-contrast scene 199, 241, 372, 396
lpi, lines per inch 279
luminance 186
luminance range 114, 115, 213
LV, light value 187

**M**

magnification, camera 191
magnification, enlarger 445, 509, 510
magnification target 192, 520
masking 256, 263, 357, 398, 403
masking kit 458
matching monitor & print appearance 495
mat cutter 64
matting prints 57, 70

measuring contrast, negative 221
measuring contrast, paper 302, 307
media life expectancy 167, 201
medium-format cameras 410
midtone gradient 195
midtones 111
minimum viewing distance 132, 509
mixing chemicals 501
modulation transfer function, MTF 141
moiré 160
monitor matching 495
mount-board 58
mounting jig 65
mounting & matting 57
mounting styles 58
MTF 141
MTF, digital 175
MTF, measuring resolution & sharpness 172
MTF system performance 180
mural prints 444

**N**

negative after-treatment 204
negative average gradient 195, 213, 220, 436
negative carrier 439
negative characteristic curve 111, 195, 516
negative, chromogenic 246
negative contrast 195, 221
negative density range 115, 196, 244
negative density table 116, 507
negative development 194, 197, 214, 216, 225, 519
negative, digital 275
negative exposure range 115
negative flatness, darkroom 439
negative formats 411
negative gradient 195, 213, 436
negative, halftone 275, 288
negative identification 463, 482
negative, inkjet 288
negative intensification 205
negative masking 256, 263
negative quality 17
negative reduction 205
negative, shadow control 235
negative spotting 76
negative stabilization 203
negative storage 206
negative toning 200
negative zones 114
Newton's rings 176, 279, 439
noise, digital 160
non-image exposure 329
normal development, film 197
normal focal length 413
normal viewing distance 132
notching film holders 465
number sequences 491

**O**

OC filter 428, 429, 430
oil print 381
optical center 63
optimal pinhole diameter 153
optimizing film speed & development 214
optimizing print exposure & contrast 295
optimum fixing time 38
organic compound 499
orthochromatic film 190
overall contrast 239
overdevelopment, film 227
overexposure, film 226, 231
overmat 58
oxid 499

**P**

painting with light 376
panchromatic film 190
panel of prints 90
paper aging 339
paper characteristic curve 111
paper contrast 28, 302
paper contrast change 315
paper contrast loss 339
paper curve 111, 296, 303
paper density range 115, 296, 303
paper developer 503
  aging 339
  dilution 339, 342
  exhaustion 342
  temperature compensation 342
paper development template 514, 518
paper, Dmax & Dmin 296, 303
paper exposure range 304, 515
paper, fixed-contrast 28
paper fixer 504
paper flasher 456
paper flashing 329, 456
paper flatness 442
paper, graded 28
paper-grade dial 523
paper grade meter 518
paper grades 29, 244, 298, 303, 309, 515
paper, latent image stability 339
paper negatives 483
paper processing 36
paper range 304
paper range meter 518
paper reciprocity failure 336
paper, spectral sensitivity 429, 442, 486
paper speed point 316
paper standard 296, 298, 303, 515
paper, variable-contrast 30, 245, 304
pen-lining easel 456
periodic table 498
permanence 50
perspective distortion, darkroom 445
pH 499
photographic chemistry 499
photographic printing 31
photographic quality 16
photon sieve 156, 524
pictorial range 105, 115
pinhole dial 156, 525
pinhole diameter 153
pinhole exposure 155
pinhole photography 149
pin registration 263, 458
pixel, digital 158
plastic glazing 83
point light source 435
polysulfide toning 40
portrait lighting 365, 374, 386
positioning, print 63, 65
posterization 124, 163
ppi, pixels per inch 279
pre-exposure, film 233
preservatives 500
pre-soak, film 200
print bleaching 343, 389
print burning 33, 374, 379, 393, 477
print contrast 28, 32, 295, 299
print density differentiation 297
print density discrimination 297
print density limits 296, 303
print density range 115, 296, 303
print density table 116, 507
print deterioration 48
print developer 503
print development 35
print display lighting 296
print, Dmax & Dmin 296, 303
print dodging 33
print dry-down 347
print drying 47
print easel 455
print edition size 92
printer resolution 177
print evaluation 296, 424, 425
print exhibition 90
print exhibition lighting 296
print exposure 23, 32, 295
print exposure table 317
print exposure timing 23
print finishing 57, 76, 81
print fixer 504
print fixing 36
print flashing 329, 456
print flatness 442
print fogging 329
print framing 81
print glazing 82
print highlights 32
print identification 71, 75
print illumination 296
printing basics 31
printing frame 455
printing map 27, 34
printing mask 357, 396, 402
printing records 480, 522
print, latent image stability 339
print magnification 445, 509, 510
print manipulation 374
print & monitor matching 495
print mounting & matting 57
print orientation 63
print panel 90
print permanence 50
print positioning 63, 65
print processing 36
print processor 450

print protection 81
print quality 18, 225, 231
print records 480, 522
print shadow control 32, 263, 326
print spotting 76
print stabilization 47
print storage 49
print toning 39
print viewing 296
print viewing distance 132, 509
print visualization 106, 466
print washer 451
print washing 45
print zones 114
process control 255
processing chemicals 502
processing, film 194
processing, print 36
process timer, darkroom 452

## Q

quality 16, 139, 170, 225, 231
quality control 251

## R

rangefinder camera 145, 410
rapid fixer 36
Rayleigh criterion 137
RC, resin-coated paper 35
reciprocity failure 187, 336
record keeping 480, 522
reduction, negative 205
reduction, print 343
reflected light 186
reflected lightmeter 416
reflection density 434, 493
reflection density table 507
reflection step tablet 306
reflective objects, lighting 362
rendering intent 495
reproduction 103
reproduction cycle 117
residual thiosulfate limits 45, 201
resolution, digital 171, 174, 177, 279
resolution, digital camera 176
resolution equations 180
resolution, film 208, 209
resolution, halftone 280
resolution, human eye 8, 132
resolution, lens test 132
resolution limits 138
resolution limits, digital 161, 176
resolution, MTF measurements 172
resolution, printer 177
resolution requirements, digital 171, 174, 176, 177
resolution requirements, film 133, 509
resolution, scanner 176, 178
resolution, sensor 172
resolution, system performance 180
resolution target 132
restrainers 500
rim light, studio 365
roll film 146, 201, 411

## S

safelights 424
safelight test 428, 432
safety 427, 502
salt 499
scanner resolution 176, 178
scanners 175
Scheimpflug principle 445
seawater 501
selenium toning 42
sensitometry 110
sensor resolution, digital 172
shadow contrast 195
shadow control, negative 235
shadow control, print 32, 263, 326
shadow discrimination 297
shadow gradient 195
sharpness 131, 139, 140, 143, 208, 209, 256, 437, 438
sheet film 146, 201, 411
shopping list, chemicals 502
shoulder, film & paper 111, 120, 195
shutter 412
shutter accuracy 414
shutter speed 491
shutter tester 414, 470
silver estimator 39
silver stabilizer 47
single-filter method, VC printing 311
sink, darkroom 426, 427
slot processor 451
SLR, single-lens reflex camera 410
small-format cameras 410
solarization 111
spectral sensitivity, camera filter 190
spectral sensitivity, darkroom filter 429
spectral sensitivity, film 190
spectral sensitivity, human eye 7, 190
spectral sensitivity, lightmeter 190
spectral sensitivity, paper 429, 442, 486
specular density & reflection 434
speed point, film 213
speed point, paper 316
spi, samples per inch 279
split-grade printing 318, 324, 359
split toning 44
spotmeter 416
spotting 76
stabilization 47, 203
standard density table 507
standard paper grades 515
standards 215, 220, 296, 303
stop bath 200, 500, 503
stop, definition 491
storage 49, 167, 206
studio lighting 365
subject brightness range 114, 115, 213
subject brightness range table 517
subject magnification 191
subject zones 114
subtractive color system 310
sulfide toning 40
system performance, optical 180

## T

tables & templates 506
tacking iron 64
telephoto lenses 413
temperature compensation
  film development 197, 513
  print development 342
temperature control, darkroom 451
temperature conversion 512
test strip 24, 218, 306, 316, 473, 474
test strip printer 472
test target, exposure 192, 520
test target, focusing 148
test target, magnification 192, 520
test target, resolution 132
test target, Zone System 252
textural range 105, 115
three-point lighting 368
timer, darkroom 452
timing exposure 23, 186, 414, 492, 508
toe, film & paper 111, 120, 195
tonal discrimination 297
tonal reproduction, digital 119
toner 40, 42, 44, 501, 504
tone reproduction 103, 113, 115
tone reproduction cycle 117
tone reproduction, digital 161, 494
tone visualization 106
toning, color change 41
toning film 200
toning prints 39
torch, darkroom 457
transfer function 277, 285, 494, 527
transmission density 493
transmission density table 507
transmission step tablet 306
transmittance 83, 493
tri-color filter 304, 319
tripods 417
two-bath fixing 36

## U

ultraviolet radiation 6
underdevelopment, film 227
underexposure, film 226, 231
unsharp masking 165, 256, 263
unsharp masking kit 458
USAF/1951 test pattern 132

## V

VC, variable-contrast filter 304, 310
VC, variable-contrast paper 30, 245, 304
ventilation, darkroom 423
vibration, enlarger 438
view camera, depth-of-focus scale 136
view camera, exposure target 192
view camera, film-holder identification 463
view camera, focusing 146
view camera, Fresnel lens 147
view camera, ground glass 146
view camera, portraits 386
viewing distance, prints 132, 509
viewing prints 296

vision, human 6, 131, 297
visual acuity 7
visualization 106, 466

**W**

warm-tone developer 503
washer, prints 451
washing 45, 201
washing aid 45, 201, 501
washing test, prints 46
water temperature control 451
wavelength 6, 138
wet side, darkroom 425
wide-angle lenses 413
Wratten 8, 11, 15, 25 filter 191
Wratten 47b & 58 filter 304, 319

**Z**

zone compression 116, 117
zone density table 507
zone dial 468, 521
zone placement 106
zone plate 156, 524
zone reproduction 114
zone ruler 466
Zone System 105
Zone System, 35 mm 245
Zone System boundaries 212
Zone System, C41 246
Zone System, dedicated film backs 245, 395
Zone System development 197
Zone System, digital 107
Zone System, high-contrast scene 198, 240
Zone System, low-contrast scene 199, 241
Zone System metering 108
Zone System, pictorial range 105, 115
Zone System, pinhole dial 156, 525
Zone System placement 394
Zone System, ruler 466
Zone System standard 211, 213, 220
Zone System, standard values 116, 507
Zone System table 116, 517
Zone System target 252
Zone System testing 214
Zone System, textural range 105, 115
Zone System, tone reproduction 114
Zone System, visualization 106, 466
Zone System, zone dial 468, 521